THE

Mule Spinning Process,

AND THE

MACHINERY EMPLOYED IN IT,

DESCRIBED WITH SPECIAL REGARD TO THE SPINNING OF MIDDLE FINE NUMBERS.

BY KURT NESTE.

ILLUSTRATED BY 11 ENGRAVED PLATES.

Manchester:
JOHN HEYWOOD, 143, DEANSGATE.
LONDON: SIMPKIN AND MARSHALL.
1865.

PRICE FOUR SHILLINGS.

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PREFACE.

Most works which have hitherto appeared upon Cotton Spinning, consist chiefly of calculations of the weight of the yarn, and instruct the spinner which alterations have to be made in the speeds of certain parts of the machines, in order to pass from one yarn number to another.

There is no doubt that this knowledge, although important in itself, is not sufficient to enable a practical spinner to know by which machine or machines any faults appearing in the yarns have been occasioned, and how they are best to be remedied. He should know besides, what object each single machine ought to accomplish, and by what means, and to what degree of perfection this can be done.

For this purpose, a thorough acquaintance with the machines used in the mills is requisite; that is to say, a knowledge of the principle and of the manner of action of the machines.

To acquire this by observation is not only difficult and tedious, in consequence of the complicated construction of these machines, but almost impossible without a certain amount of preliminary mechanical study.

The desire of the author of this treatise is to aid those who are wishing to obtain this practical knowledge with the least possible trouble.

Two points have been chiefly kept in view in editing this book:

Firstly—To require only the lowest possible degree of preliminary knowledge.

Secondly—To make the work by its low price accessible to all.

As regards the first point, an introduction precedes the book in order to enable the reader to gain a sufficient acquaintance with those mechanical contrivances which occur most frequently. Furthermore, all calculations, including the most complicated ones, which are generally found by the assistance of the more abstruse mathematical rules, are given in so simple a manner as to require only a knowledge of decimal fractions.

In order to fix the price of this book as low as possible the author has treated only of one section of Cotton Spinning, as indicated by the title, viz., the Mule Spinning Process.

The plan adopted by him is as follows:—

As already mentioned, a preliminary introduction is given for those who are not acquainted with the elements of machinery.

A detailed description of all machines follows in the order in which they are used, as well as of the alterations required in such machines for the production of the various numbers of yarn.

All the machines are then placed together, as regards their producing capabilities, with the addition of the lists of the machinery contained in several mills in operation.

The description of the machines is illustrated by drawings which are kept theoretically, as far as possible, only where it could not be avoided, constructive details are given.

PREFACE.

The machines of the same class constructed by different makers vary in their details on account of patented inventions, although the principle on which they are constructed is very nearly always the same.

For description in this work, machines from acknowledged first-rate makers only have been selected, and it will therefore not be difficult for any one who has acquired a knowledge of one machine to understand another of the same class, made by another maker.

In submitting this work to the public, the author is only influenced by the want which appears to exist for such a book, and he claims the indulgence of the reader for any omission he may find in this first attempt, which he confidently hopes will on the whole be found to contain much that is practically useful.

Any suggestion which may be made by practical and experienced persons will be received with thanks, and if this work should meet with their approval he will consider himself fully compensated for the time and trouble he has bestowed upon it.

MANCHESTER, *March*, 1865.

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CONTENTS.

ERRATA

WHICH THE READER IS REQUESTED TO CORRECT BEFORE USING THE BOOK.

Page	Line	from	
PAGE 2	LINE 2	from bottom	for t and t read t and t_1
3	3	top	for t is $\frac{90}{30}$ read it is $\frac{90}{30}$.
5	14	top	for conex read cone x.
6	11	bottom	for shifted = measured read shifted, measured.
6	6	bottom	for 14 in read = 14·in.
9	20	top	for Pomrawuttee read Oomrawuttee.
14	3	„	
14	4 & 2	bottom	for A read A_1
15	13	top	for fig. 7, Pl. II. read fig. 1, Pl. III.
15	13	„	for sieves, read sieves, perforated as fig. 7, Pl. II. shows.
15	18	top	for I I read I I_1
15	20	top	
16	7 & 8	bottom	for K read K_1
17	4	top	
18	2	„	for C and G read C and C_1
19	13	bottom	for of 13 teeth read of 63 teeth.
20	6	top	for 38 teeth read 33 teeth.
20	13	bottom	for t = 50 read t = 51.
22	2	„	for C read C_1
22	13	bottom	for $n=\frac{928,12 \times 3,125}{88 \times 3,125}$ read $n=\frac{928,12 \times 6,5}{88 \times 3,125}$
23	2	top	for $\frac{73}{19,225}$ read $\frac{73}{10,225}$
23	5	top	for — 7, 14 read = 7, 14.
24	19	bottom	for f_5 read f_7
41	2	„	for Pl. IV. read Pl. V.
42	13	top	for these read there.
48	2	„	for (n_6) read $\binom{n}{b}$
60	9	bottom	for 200 read 250.
63	3	top	for $n = \sqrt{\frac{(28)\,N}{60}}$ read $n = \sqrt{\frac{(28)^2}{60}\frac{N}{}}$
64	5	bottom	for Pl. IV. read Pl. IX.
69	2	bottom	for crop read cop.
73	5 & 8	top	for g read G.
73	3	bottom	for n read n_1
75	2	„	for field read fixed.
79	9	top	for — 11,32 in. read = 11,32 in.
80	1	bottom	for 4468 read 4568.
84	1	„	for stretchers read stretches.
85	4	„	for $\frac{25,19}{}$ read $\frac{25,19}{5}$

On Plates I., IV., and VII. for T and T_1 read F and F_1

INTRODUCTION.

In order to be able to go through the various calculations necessarily occurring in a work like the present, in the most concise and simple manner, the author has deemed it desirable to introduce the following short treatise upon some of the mechanisms most frequently used in spinning machinery, namely—pulleys, toothed wheels, cones, and levers, hoping it will be found acceptable by those of his readers who have not had an opportunity of acquiring much theoretical knowledge.

There are many mechanical contrivances in use for transmitting rotatory motion from one axis to another, only three of which however are of importance in cotton machinery, viz., pulleys, toothed wheels, and surfaces described by the rotation of a hyperbola round its axis.

PULLEYS AND WHEELS.

If we fix a pulley on a shaft having a rotatory motion, and another of the same diameter on a second shaft, and place a continuous or endless strap over both, the second shaft will make the same number of revolutions as the first, provided the position and construction of the pulleys do not allow the strap to fall off, and the tension of the latter be sufficient to prevent it from slipping or sliding on the pulley. *Fig.* 1, *Plate I.* This requires no further proof, because the strap, having the same velocity as the circumference of the driving pulley, imparts this velocity to the circumference of the second pulley.

As both pulleys have always the same circumferential velocity and as that of the driving pulley increases with the circumference of this pulley (the number of revolutions remaining the same), the circumferential velocity of the driven pulley also increases with it; for the same reason it grows less, if the circumference of the driving pulley decreases.

A similar change in the velocity of the driven pulley takes place if the driving pulley remains unchanged, and the driven pulley is made smaller or larger.

As the ratio of the circumferences of two circles is the same as that of their diameters, we draw the following general conclusion :—

The ratio of the number of revolutions per minute or second of the driving shaft to the number of revolutions of the driven shaft, is the same as that of the diameter of the driven pulley to the diameter of the driving pulley, or, $n : n_1 = d_1 : d$; where n and n_1 are the numbers of revolutions, and d and d_1 the diameters of the pulleys respectively for the driving and the driven shaft, consequently $n_1 = \frac{nd}{d_1}$

If, for instance, a shaft makes 90 revolutions per minute, and carries a 12in. pulley, acting upon another of 36 inches on a second shaft, the number of revolutions of this shaft will be $\frac{90 \times 12}{36} = 30$, *Fig.* 2.

Both pulleys turn in the same direction; if the driven pulley is to turn in the opposite way, the strap must either be crossed in placing it upon the pulleys, as in *Fig.* 3, *Plate 1*, or a third pulley must be used in some appropriate way. *Fig.* 4.

If a machine shaft driven from the main shaft by pulleys and strap is to be thrown out of gear, the strap is either entirely thrown off the pulleys or guided upon a pulley running loose on its shaft (loose pulley), which may be either on the machine shaft or the main shaft. *Fig.* 5.

If the rims of both pulleys are brought into contact, and pressed sufficiently against each other so that no slipping can take place, the driven pulley will be taken round by the driving one as before, but the direction of its revolution will be opposite. *Fig.* 6.

To avoid this pressure, which would soon wear the bearings out, the rims of both pulleys are provided with teeth working one into the other, by which the second shaft is turned in the same manner. The circles out of which we can suppose the toothed wheels to have been made, are called pitch circles. The numbers of teeth of two correctly made wheels gearing one with the other, must be in the same proportion as the diameters of their pitch circles.

It follows that the numbers of revolutions of two shafts connected by toothed wheels are in inverse ratio to the numbers of teeth. If we call again the numbers of revolutions n and n_1, and the numbers of teeth t and t then we have $n : n_1 : : t_1 : t$; $n_1 = \frac{nt}{t_1}$. For instance, if $n = 90$, $t = 20$, $t_1 = 60$, then $n_1 = \frac{90 \times 20}{60} = 30$. *Fig.* 7.

The number of revolutions of the driving shaft, divided by that of the driven shaft, is called the velocity-ratio; for the above example t is $\frac{90}{30} = 3$. If the motion were transmitted in the reverse way from the driven to the driving shaft, the velocity-ratio would be $\frac{30}{90} = \frac{1}{3}$.

If the ratio is more than 10, for instance, 20, it is divided into two nearly equal factors, say 4 × 5, and an intermediate shaft is used, making 1 revolution to 5 of the driving shaft; upon this intermediate shaft a pinion is fixed working into a wheel on the driven shaft with four times the number of teeth. If, for instance, the main shaft makes 100 revolutions, and the second shaft is to make 5, the velocity-ratio is $\frac{100}{5} = 20$. If we use a pinion with 10 teeth on the main shaft, the wheel on the intermediate shaft must have 50 teeth, then another pinion of 10 teeth is keyed on the latter, working with one of 40 teeth on the second shaft; consequently,

$$n_1 = \frac{n \times 10 \times 10}{50 \times 40} = \frac{100 \times 10 \times 10}{50 \times 40} = 5.$$

For calculating the numbers of revolutions of a shaft, we therefore have the following rule :—

Multiply the number of revolutions of the driving shaft by the numbers of teeth of all driving wheels or pinions, and divide this product by the product of the numbers of teeth of all the driven wheels. If pulleys are used simultaneously, multiply in the same way by their diameters.

Example :—The shaft *a*, *Fig.* 9, makes 300 revolutions, and carries a pinion of 16 teeth working into a wheel of 100 teeth; on the shaft of the latter a pulley of 4in. diameter is fixed, driving another of 15in. diameter on a third shaft; on this a pinion of 12 teeth is keyed on, gearing into a wheel of 50 teeth on a fourth shaft. How many revolutions does the latter make?

According to the rule $n_1 = \frac{300 \times 16 \times 4 \times 12}{100 \times 15 \times 50}$; after dividing dividend and divisor by the common factors 100 × 3 × 2, we have

$$\frac{8 \times 4 \times 12}{5 \times 25} = \frac{384}{125}$$

```
125 ) 384 ( 3,072 = n1.
      375
      ---
       900
       875
       ---
        250
        250
        ---
```

The shaft accordingly makes 3,072 revolutions.

If both shafts are to turn in the same direction, an intermediate wheel (carrier wheel) must be used, that has however no influence upon the velocity-ratio, *Fig.* 10. According to the distance of the two shafts, any number of carrier wheels may be applied, both shafts turning in the same direction if the number of wheels is uneven, and opposite to one another if their number is even.

If the distance of the two shafts is considerable, and the motion still to be transmitted by wheels, a third shaft must be placed in such a position as to intersect the direction of both the others, this intermediate shaft being put in motion from the driving shaft through a pair of bevel wheels, and driving in its turn the second shaft by another pair of bevel wheels.

Regarding the kinds of wheels used for different positions of the shafts, it is to be observed that: Parallel shafts are connected by spur wheels, shafts intersecting each other by bevel wheels; shafts that are neither parallel nor intersect each other, either by bevel wheels with skew teeth, or by an intermediate shaft, whose direction intersects the two others. *Figs.* 8, 11, 12, and 13.

For counting apparatus, and where not much power has to be transmitted, worms and worm-wheels are used. For every revolution of the worm, the worm-wheel moves one tooth, so that for one revolution of a worm-wheel of 100 teeth, the worm must make 100. The speed can of course be further diminished from the worm-wheel shaft by toothed wheels; for instance, by fixing a pinion of 10 teeth upon the axis of the worm-wheel, and letting it act upon a wheel of 100 teeth, the latter will only make one revolution for 1000 of the worm, and so on. *Fig.* 14.

CONES.

Pulleys as well as toothed wheels can only be applied when the driven shaft is to turn with a constant velocity; but if the latter is to be varied, cones or conical rotatory surfaces have to be used.

Fig 15 shows a pair of cones of equal size, but placed reversely parallel to each other. The strap must be guided so as to be always parallel to its original position. The effect of this arrangement regarding the number of revolutions for any position of the strap, is the same as if the latter was running on two pulleys of the same diameters as those of the circles described by the centre-line of the strap on each cone. If, for instance, the strap is running in such a place that the diameter of the circle described by its centre on the driving cone

is $= 9''$, while that of the circle traced on the other cone is $= 5''$ and if the driving cone makes 100 revolutions, then n for the other cone will be

$$\frac{100 \times 9}{5} = 180.$$

In order to retain always the same tension in the strap, the sum of the diameters of two corresponding circles must remain constant, or equal to the sum of the top and bottom diameters of each cone.

Suppose the diameter of the large end to be 10in., that of the small one = 4in. If the strap stands exactly in the middle, the diameter of each circle will be = 7in., consequently no alteration of speed will take place. Suppose, further, the side of each cone to be 36in. long. If we now imagine the cone completed, as shewn with dotted lines on *fig.* 15, and call the length of the side of the supplementary conex, we can calculate x by the following proportion:—

$$x : (36 + x) \; : : \; 4 : 10$$
$$\text{Or } 10x = 4x + 144$$
$$6x = 144$$
$$x = \frac{144}{6} = 24\,;$$

making the whole length of the cone from the apex = 36 + 24 = 60in.

We now proceed from the middle position of the strap, where the distance of its centre from the apex is 24in. + 18in. = 42in., and the diameter of the circle traced by it = 7in. The same also results from the proportion $24 : (24 + 18) \; : : \; 4 : d_1$,—the diameter d_1 of that circle being =

$$\frac{168}{24} = 7\text{in.}$$

If we now move the strap one inch, measured on the side of the cone, towards the top end of the driving cone, the diameter of the circle described on the latter by the strap in this position, d_2, is =

$$\frac{4 \times (24 + 17)}{24} = \frac{41}{6} = 6{,}8333\ldots$$

The corresponding diameter, δ_2 of the other cone is $14 - d_2 =$ 7,1666 . . , n being = 100, we find

$$n_1 = \frac{100 \times 6{,}8333}{7{,}1666}$$

```
7,1666 . . . ) 683,333 . . . ( 95,35 = n1
               644,999
               -------
                383333
                358333
                ------
                 250000
                 214999
                 ------
                  35000
```

After moving the strap in the same direction another inch further on, measured on the side of the cone, we find in the same manner—

$$d_3 = \frac{(24 + 16)}{24} = \frac{40}{6} = 6{,}666\ldots$$

$$\text{And } \delta_3 = 14 - 6{,}666\ldots = 7{,}333\ldots$$

$$n_1 \text{ is } \frac{100 \times 6{,}66}{7{,}333\ldots}$$

$$7{,}333\ldots \Big)\begin{array}{l}666{,}666\ldots\\659{,}999\\\hline 666666\\659999\\\hline 6666\end{array}\Big(\,90{,}90$$

Continuing these calculations for other positions of the strap, shifting it from inch to inch, we obtain the following table :—

Distance of centre of strap from the apex.	d	δ	n_1	Decrease in the number of rev.
42	7	7	100	
41	6,8333..	7,1666..	95,35	4,65
40	6,6666..	7,3333..	90,90	4,45
39	6,5	7,5	86,66..	4,24
38	6,3333..	7,6666..	82,60	4,06
37	6,1666..	7,8333..	78,72	3,88
36	6	8	75	3,72

From this table it is evident, that the decrease in the number of revolutions for a shift of the strap of one inch becomes the less, the nearer the latter approaches the top of the driving cone, and consequently that it is not proportional to the lateral travel of the strap. If, on the contrary, the rotatory motion is to be transmitted in such a manner that the decrease in the number of revolutions of the driven shaft is proportional to the lateral travel of the strap on the cone, we must adopt the following proceeding which we however only touch upon, this being the task of the machinist.

Suppose that the driving shaft makes 100 revolutions, and that it is required the number of revolutions of the driven shaft should decrease from 250 to 40, in such a manner, that it is diminished by 6 for every inch the strap is shifted = measured on the axis of the cone.

The length of the axis of the cone must therefore be $\frac{250-40}{6} = 35''$. If we now make for example the largest diameter of the driving cone = 10″, the corresponding smallest diameter of the other cone must be $= \frac{100 \times 10}{250} = 4''$. The sum of the two $d + \delta$ 14in.

We now divide a line of 35in. forming the axis, into 35 equal parts of one inch each, and draw through the divisions lines vertically to the axis. On the first of these lines we cut two inches off on each side of the axis.

The length of the second line is found by the following calculations:

After shifting the strap one inch, the second cone is to make 244 revolutions, accordingly $100 \times d_2$ must be $= 244 \times \delta_2$.

Or $d_2 = \frac{244}{100} \delta_2 = 2{,}44\ \delta_2$ I

$d_2 + \delta_2$ must be $= 14$; consequently $d_2 = 14 - \delta_2$ II.

By placing the two values of d_2 in I and II equal to each other, we have

$$2{,}44\delta_2 = 14 - \delta_2$$
$$\delta_2 + 2{,}44\ \delta_2 = 14$$
$$\delta_2\ (1 + 2{,}44) = 3{,}44\ \delta_2 = 14$$
$$\delta_2 = \frac{14}{3{,}44}$$

```
3,44)1400(4,069"
     1376
     ----
      2400
      2064
      ----
      3360
```

We now cut one half of this value of 4,069in. off the second vertical on each side of the axis.

In the same way we find

$$\delta_3 = \frac{14}{3{,}38} = 4{,}142\text{in.}$$

half of which is cut off the third vertical on each side of the axis.

For δ_4 we obtain the following value:

$$\delta_4 = \frac{14}{3{,}32} = 4{,}216\text{in.}$$

the length of the fourth vertical on each side of the axis must therefore be $\frac{4{,}216}{2}$ in.

$$\delta_5 \text{ we find } = \frac{14}{326} = 4{,}294$$

In this way we continue to the end and then connect the ends of all the verticals by a continuous curve. By turning this curve round the axis we obtain the required surface of the driven cone.

On examining this curve we find it to be a hyperbola; to enter into this examination is however beyond the limit of our task.

We now find the curve for the driving cone by deducting the values of δ from 14in., and cutting one half of the rest thus obtained off the corresponding verticals, drawn at one inch distance on a line 35in. long, and connecting their ends. This curve corresponds with the former; but that for the driving cone F is concave, while that for the other cone F_1 is convex, *Fig.* 16.

Note.—In Fig. 16 the curves are shown to deviate more from the straight line than they do according to the above mode of construction, this has merely been done to keep the lines more distinct.

LEVERS.

Suppose *a (Fig.* 1, *Plate* II*)* to be the pivot of a lever, the long arm to be 20in., the short one 2in., and a weight of 10 lbs. to be suspended at the end of the long arm ; then a weight of 100 lbs. is required at the end of the short arm to restore equilibrium, the weight of the lever itself being left out of consideration. This is found by the following equation:—

$$20 \times 10 \text{ lbs.} = 2 \times x$$
$$x = 100 \text{ lbs.}$$

Where x signifies the desired weight. If the short lever instead of carrying a weight of 100 lbs., presses on some point, this pressure will be equal to 100 lbs.

We find the pressure exercised through a lever by multiplying the weight by its distance from the fulcrum of the lever, and dividing this product by the distance of the point where the pressure is exercised from the fulcrum.

The length of the first distance divided by that of the latter is the ratio of leverage; in the above example it is $\frac{20}{2} = 10$.

For exercising an equal tension instead of pressure, the lever may be suspended by a rod *(Fig.* 2, *Plate II.)* in such a way that the length of the longer arm divided by that of the shorter one is equal to the ratio. It is not necessary for the lever to turn on a pivot, but it may rest with an edge against some fixed surface. The length of the long arm is in this case the length of the entire lever; if therefore the ratio is again to be 10, and the point of suspension is 2 inches distant from the edge, the entire lever must be 20 inches long.

A large ratio of leverage, for instance 100, may be divided into two factors, say 10 and 10. In this case a tension rod is snspended at the end of the first lever instead of the weight of 10 lbs., by which a second lever is supported in such a manner that the quotient of the long arm divided by the short one is again = 10. In this case a weight of 1 lb. exercises a tension of 100 lbs., the weight of 10 lbs. consequently a tension of 1000 lbs., *Fig.* 3, *Plate II.*

Levers are also used for multiplying the length of motion or travel. If we turn the lever in *Fig.* 4, *Plate II.*, round its pivot *a*, till the distance of the end of the short arm from its original position is for instance one inch, and if the long arm is fifteen times as long as the short one, its end will travel in the same time 15 inches.

COTTON.

Cotton is a downy substance, consisting of separate fibres, which envelopes the seed kernels, and is enclosed in the capsules of the cotton plant.

The cotton plant is either grown every year from seeds and produces cotton only once, or it is a perennial shrub, yielding an annual crop for several consecutive years.

Although the number of species of the cotton plant is very limited, yet the produce shows great variety. The temperature, the weather, and the nature of the soil exercise such an extraordinary influence upon the quality of the cotton, that every one of the cotton growing countries produces a special kind with particular qualities. As the cultivation of the cotton plant has lately extended to nearly every country, the number of different kinds and of their names has been extraordinarily increased.

We must, however, confine ourselves to the enumeration of those kinds used for middle numbers of yarns (from 20 to 80), and of these we only mention such as find frequent application in consequence of their being brought into the market in large quantities. They are :— Chinese and Japanese cotton, the kinds called Surat, as Dhollera and Comptah, and the inferior Pomrawuttee, then American, and lastly, Egyptian cotton.

The quality of the cotton is estimated according to the length of its staple, its fineness, softness, strength, evenness, and colour. The best kind is the so-called Sea-Island cotton, and the worst Bengal cotton.

The article made from the cotton is the yarn, which must have the same number of fibres in every cross section, and the same amount of twist for every unit of length. Twist we call the number of turns of the fibres round the axis of the thread. As the thickness of the yarn, and consequently its weight, depend from the number of fibres in a cross section, the fineness of the yarn is determined by the ratio of the weight of a certain length of yarn to one pound. The length used for this purpose is the hank, and we call for instance the number of a yarn 30, if a length of 30 hanks weighs one pound.

One hank = 840 yards or 7 leys
One ley therefore = 120 yards,

If we designate the number of the yarn by N, the weight of one hank by G, and the weight of one ley. by g, then N × G = 1lbs. = 7000 grains, therefore $N = \frac{7000}{G}$

and $N = \frac{7000}{7g} = \frac{1000}{g}$

Two divisions of weights are in use, as is well known.

1st Division. Avoirdupois weight.

$27\frac{11}{32}$ grains = 1 drachm = $27\frac{11}{32}$ grains.
16 drachms = 1 ounce = $437\frac{1}{2}$ grains.
16 ounces = 1 pound = 7000 grains.

2nd Division.—Troy Weight.

24 grains = 1. pennyweight = 24 grains.
20 pennyweights = 1 ounce = 480 grains.
12 ounces = 1 pound = 5760 grains.

For weighing the various products of spinning a combination of these two divisions of weight is used. It is usually said that pounds and ounces are avoirdupois weight, but pennyweights and grains troy weight.

A pound is divided into 16 ounces.
1 ounce = $437\frac{1}{2}$ grains.
1 lb. = 7000 grains.

And 24 grains are reckoned as = 1 pennyweight.

This is quite sufficient for expressing the weight of large quantities, where pounds and ounces or fractions of an ounce are accurate enough, or for determining the weight of very small quantities, which require only grains and pennyweights.

If, however, for instance, the weight of a hank of yarn or roving is to be found, which is done by weighing a ley or a quarter ley, this division becomes very inconvenient, because the connecting link between ounces and pennyweights is wanting.

The following division is often found in use in mills:—

24 grains = 1 pennyweight = 24 grains.
20 pennyweights = 1 ounce = 480 grains.
16 ounces = 1 pound.

But 16 × 480 = 7680, consequently this gives a pound, which is too heavy by 680 grains.

In order to find how many pennyweights there really are in one ounce, 7000 must be divided by 16 × 24. We find

$$\frac{7000}{16 \times 24} = \frac{7000}{384} = 18,229125$$

So that troy and avoirdupois division are to be connected in the following manner.

24 grains	= 1 pennyweight =	24 grains.
18,229125 pennyweights	= 1 ounce =	437,5 grains.
16 ounces	= 1 pound =	7000 grains.

To carry out the reductions according to this division would make the calculations exceedingly cumbersome. If, for instance, 30 yards of roving weighed 3 pennyweights, consequently 1 hank 3 × 28 = 84 pennyweights, 84 would have to be divided by 18,229125 to find the ounces; and the decimals of the rest left must be multiplied by 24 to find the grains.

In order to avoid this, it is best to make the calculations in grains, when the reduction is ascending, as in this case, or in pounds and fractions of pounds when it is descending.

In the example before us, 30 yards of roving weighed 3 × 24 = 72 grains, consequently a hank weighs 28 × 72 = 2016 grains. For reducing these into ounces and pennyweights, this figure must be divided by 437,5, and the rest by 24, thus—

```
4375 ) 20160 ( 4 ounces.
       17500
  24 / 266 / 11 pennyweights.
       24
        26
        24
         2 grains.
```

A hank accordingly weighs 4oz., 11dws., 2grs. To find how many hanks go to 1lb., 7000 must be divided by 2016; we obtain

$$\frac{7000}{2016} = 3,472$$

For converting these 0,472 hank into yards, 472 must be multiplied by 840, and divided by 1000.

$$\frac{472 \times 840}{1000} = 396,48 \text{ yards},$$

Consequently a length of 3 hanks 396½ yards, weighs 1lb.

The following example may shew the manner of proceeding when the reduction is descending:

Supposing the total draught or stretching, which the cotton receives in passing through the double and single scutcher, and the carding engine, to be 150¼.

If under these circumstances 4lbs. of cotton are spread upon 1 yard of the feed lattice of the double scutcher, they turn out as sliver from the engine-head, in a length of 150¼, or 150,25 yds.

If the cotton loses 10 per cent. during this process, the weight of these 150¼ yards becomes $\frac{90 \times 4}{100} = 3,6$ lbs., and the weight of a length of 30 yards becomes $\frac{3,6 \times 30}{150,25} = 0,7188$lbs.

If this were to be reduced into ounces, pennyweights, and grains, in the usual way of such reductions, we should have to multiply 7188 by 16, and then cut 4 figures from the right off as decimals (*i.e.*, divide by 10000); then we should have to multiply these decimals by 18,229125, and cut 10 decimals off the product; these would have to be multiplied again by 24, and 10 decimals would have to be cut off.

Instead of this cumbersome operation, we convert the 0,7188lbs. at once into grains by multiplying it by 7000, and then make the reduction into ounces and pennyweights ascending as in the preceding example.

```
0,7188 × 7000 = 5031,6000 grains.
437,5 ) 5031,6 ( 11 ounces.
        4375
        ------
         656,6
         457,5
        ------
24    )  219,1 ( 9 pennyweights.
         216
        ------
           3,1 grains.
```

The weight of ¼ ley of sliver from the engine-head consequently is = 11oz., 9dws., 3,1grs.

This example also may serve to show the manner in which the loss or waste of the cotton in passing these machines is calculated.

If, for instance, under the above conditions of the draught and feeding, the weight of ¼ ley of sliver has been ascertained (by weighing it on a pair of scales) and found to be 12oz., the weight of 150,25 yards must first be calculated. Twelve ounces are 5250 grains, consequently the weight of 150,25 yards is

$$\frac{150,25 \times 5250}{30} = 26293,75 \text{ grains.}$$

To reduce these into pounds they must be divided by 7000—

$$\frac{26293,75}{7000} = 3,75625\text{lbs.}$$

We have now the proportion—

$$4\text{lbs.} : 3,75625\text{lbs.} = 100 : x$$

$$x = \frac{375,625}{4} = 93,9$$

The cotton therefore has lost 100 — 93,9 = 6,1 per cent.

The loss suffered by the cotton in passing through the opener can be ascertained simply by weighing ; by passing, for instance, 100lbs. through the opener, and deducting the weight of the opened cotton delivered from these 100lbs.

This loss added to the one calculated before gives the total loss or waste.

The cotton is brought into the market in bales of 300 to 400lbs., firmly compressed by hydraulic pressure. The greatest part of the seeds have been removed by the machines called gins, before packing. In many kinds, however, a large quantity of them is still left, which jointly with various other impurities amounts to 10 to 30 per cent. of the gross weight of the cotton.

Before the thread can be formed, the cotton must be loosened and cleaned, then all the fibres must be placed parallel to each other, and a uniform section must be arrived at.

This is effected by a series of preparatory machines, which we will describe one after the other.

MIXING.

The first process is the *mixing*, generally done in the following way. The contents of one bale are spread out in a layer, the thickness depending upon the number of bales to be mixed, upon this the contents of a second bale are spread, and so on. Frequently the cotton is damped a little during this operation, to make the fibres better adapted for stretching. Generally different kinds are mixed ;

and we give in the following table a sample of the proportion of the separate sorts for various numbers of yarn.

No.	China or Japan.	Pomrawuttee.	Dhollera or Comptah.	America.	Egypt.
20 to 28		1			
	½		½		
	⅓	⅓	⅓		
	¼	½	¼		
28-36			1		
	¼	½		¼	
	⅓		⅓	⅓	
	½			½	
36-46		⅓		⅔	
			½	½	
46-60				1	
			⅓	⅓	⅓
			¼	½	¼
60-70				⅔	⅓
70-80				½	½
above 80					1

Another method of mixing, especially practised when three kinds of cotton are used in equal quantities, is the following: each kind is mixed by itself on the plan described above, after which a number of lap fleeces are made of each kind; then three laps, one of each sort, are placed upon a single scutcher, and by it united into one, as will be shewn hereafter.

After the mixing has been effected in the first manner, vertical slices are taken off the same to supply the opener.

OPENER.

The object of the opener is to open out or loosen the fibres of the cotton, and to remove the coarser impurities, as seed, dry leaves, parts of the pods, &c. The machine has the following construction: A (*fig* 1, *Pl.* III) is an endless feeding lattice, made of wooden staves (*fig.* 5, *Pl.* II), fastened to three parallel straps. On the shaft, A_2, three pulleys are keyed on, communicating their rotatory motion to the feed lattice. A is another shaft, with three similar pulleys running loose on it, which are taken round by the feed cloth. To keep the latter tight, the distance between the shaft A and A_2, is adjustable by two screws, one acting on each end of the shaft A (*fig.* 8, *Pl.* II).

The cotton is spread upon this feed cloth, and taken forward by it and the ribbed roller *B* (*fig.* 5, *Pl.* II) to the fluted feed rollers C, C_1; after passing these, it is seized and carried forward by the teeth of the first cylinder *D*. Below the cylinder, and concentric with it, is a grid formed of sharp-edged iron bars *e*, between which and the teeth *h* the cotton is opened, the seed being stripped off against the bars. This process is repeated between D_1, E_1; D_2, E_2; and D_3, E_3, when the cotton is delivered upon the straight grid *F*. The latter is formed by iron bars, having alternately equal depth, *Fig.* 9, *Pl.* II. and closed below by a board turning on hinges, and pressed by a lever against the bottom of the bars. Between the tops of the bars a space is left of one-eighth of an inch in width.

G and G_1, *Fig.* 7, *Pl.* II, are two revolving cylinder sieves, between which the cotton dissolved into flakes is guided. *H* is a fan, so arranged as to exhaust the air from the inside of both cylinder sieves.

Emerging from these, the cotton is seized by the rollers *II*, and so finally carried to the delivery lattice *K*, which is put into motion similarly to the feed lattice *A*, by three pulleys keyed on the revolving shaft *K*.

The whole space from *C* to *I* is encased by sheet iron on all sides, so that the air required for replacing that exhausted by the fan, is forced to enter between the bars of the grids *E* to E_3. The current of air thus created prevents the light cotton flakes to fall through between these bars, and forces them upon the sieve cylinders. The heavier impurities fall through between the bars of the grid *F*. during this progress of the cotton flakes, and are removed from time to time by lifting the lever, while the fine dust is forced inside the sieve-cylinders and blown out by the fan.

The cylinder D has 12 rows of teeth, *Fig.* 6, *Pl.* II, while each of the other cylinders has only four rows.

The machine is driven in the following manner:

On the shaft of the cylinder D_1 a pulley of 10in. diameter is keyed on, making 1000 revolutions per minute.

If the main shaft makes 132 revolutions, (as we will suppose it to do for all the various machines,) the driving pulley must have a diameter of $\frac{1000 \times 10}{132} = 75\frac{3}{4}$in.

If a pulley of such a large size is objectionable, a counter shaft may be used, and the velocity ratio $= \frac{1000}{132} = 7{,}5757$ divided into two factors, for instance 3 and 2,525. If we now place a 30in. pulley

on the main shaft, and a 10in. one on the countershaft, the other pulley on the countershaft, driving the opener, must have a diameter of

$$\frac{1000 \times 10 \times 10}{132 \times 30} = 22{,}73\text{—or nearly } 22\tfrac{3}{4} \text{ inches.}$$

The countershaft may also be avoided, by running the main shaft for all the preparatory machines at a greater speed. We will, however, retain our first supposition, namely, that the driving pulley on the main shaft is $75\frac{3}{4}$ inches in diameter. It must be sufficiently broad to carry two straps at the same time. One of them drives, as already stated, the cylinder D_1, and simultaneously D_3; the pulley on the latter having 8in. diameter. The second strap drives D with a 12in., and D_2 with a 9in. pulley.

As the number of revolutions stands in inverse ratio to the diameters of the pulleys—

$$n \text{ for } D \text{ is } \frac{1000 \times 10}{12} = 833\tfrac{1}{3}$$

$$n \text{ ,, } D_2 = \frac{1000 \times 10}{9} = 1111{,}11$$

$$n \text{ ,, } D_3 = \frac{1000 \times 10}{8} = 1250$$

Another $7\frac{1}{4}$in. pulley, on the shaft of the cylinder D_3, drives a 6in. pulley on the fan shaft, the latter accordingly making $\frac{1250 \times 7\frac{1}{4}}{6} =$ 1510,41 revolutions.

The other moving parts of the opener receive their motion from an intermediate shaft placed in the front part of the machine, driven direct from the main shaft, and making $16\frac{2}{3}$ revolutions. If the pulley on this shaft has a diameter of 24in., the driving pulley on the main shaft must have one of $\frac{24 \times 16\frac{2}{3}}{132} =$ nearly 3in. This is generally the diameter of the main shaft itself, and the strap is placed directly on it, without a pulley being required. If the shaft is more or less than 3in., the pulley on the machine shaft must be made proportionately more or less than 24in.

On this intermediate shaft there is, firstly, a pinion of 24 teeth, driving the shaft K, by a wheel of 36 teeth. As the pulleys keyed on K have $3\frac{1}{4}$ inches diameter, their circumference is $3{,}14 \times 3{,}25 = 10{,}215$, and their circumferential velocity $10{,}215 \times 11{,}11 =$ 113in., this being also the speed at which the delivery lattice K travels.

The same pinion of 24 teeth also drives the lower sieve-cylinder by a wheel of 81 teeth, which consequently makes $\frac{16{,}66 \times 24}{81} =$ 4,93 revolutions.

The upper sieve cylinder is provided with a wheel of 120 teeth, gearing with that of 81 teeth on the lower cylinder shaft, and making $\frac{16,66 \times 24}{120} = 3\frac{1}{3}$ revolutions per minute.

The roller I is driven in the same way as K, taking the upper roller I_1 round by two spur wheels of equal diameter. Both rollers have the same diameter as the pulleys on K_1, consequently also the same circumferential velocity of 113 inches.

The intermediate shaft further carries a bevel wheel of 24 teeth, gearing into another of 40 teeth on a side shaft; on the other end of the latter another bevel wheel of 24 teeth is fixed, working into a fourth of 40 teeth, on a shaft below the feed roller C. This shaft therefore makes $\frac{16,66 \times 24 \times 24}{40 \times 40} = 6$ revolutions.

It drives firstly A_2 at the rate of one revolution of A_2 to $1\frac{1}{2}$ of the shaft, A_2 making consequently four revolutions. The pulleys keyed on A_2 have 3in. diameter; the feed lattice A accordingly travels $4 \times 3,14 \times 3 = 37,68$ inches per minute.

This shaft drives secondly the lower feed roller by equal sized wheels, the roller making also six revolutions. As its diameter is 2,5 inches, its circumferential velocity is $2,5 \times 3,14 \times 6 = 47,1$in. The top roller is taken round by contact with the bottom one, so as to have the same circumferential velocity.

The roller B is put in motion from A_2, the pinion on A_2 having 38 and the wheel on B 31 teeth. The roller therefore makes $\frac{4 \times 38}{31}$ $= 4,6$ revolutions; its diameter being $3\frac{1}{4}$in., the circumferential velocity is $3,14 \times 3,25 \times 4,6 = 47$in.

Both feed rollers are fluted, and the top one pressed against the bottom one by levers and weights.

Instead of this opener, which is chiefly used for short staple cotton, various similar machines are applied, most of which however are constructed on the same principle. Fine cotton of a long staple is generally cleaned by a willow, because it contains less impurities, and would be damaged by the opener. For inferior kinds, however, the willow is entirely out of use; we therefore omit describing it.

DOUBLE SCUTCHER.

This machine cleans the cotton of the greatest part of the remaining impurities, and forms it into a lap.

We describe in the following pages a double scutcher as made by Parr, Curtis, & Madely, and furnished with Lord's feed regulator.

A—*Fig.* 2, *Plate III.*—is an endless feed cloth; B a fluted roller turning loose on its axis; C and G the feed rollers. The cotton is spread on the feed cloth, and conveyed to the feed rollers by it and the roller B, the latter being taken round by contact with the cotton.

D is a beater, with two blades, *d d*, standing opposite each other, at 17¾in. distance, which, quickly revolving, strike the cotton when it emerges from the feed rollers. Below the beater is a grid concentric with the way described by the blades, and formed of sharp-edged iron bars, d_1, with spaces of about ½in. between them. By the beater, assisted by these bars, the cotton is dissolved into flakes, while the seed kernels and other coarse admixtures fall through the grid. F is a fan exhausting the air from the inside of the two sieve cylinders, E and E_1; the space between the feed rollers and the back part of these cylinders is enclosed by sheet iron on all sides, so that the air required for replacing the exhausted quantity can only enter between the bars of the grid. The current of air thus created prevents the cotton flakes from falling through the grid, but carries them up to the sieve cylinders, between which the cotton passes as between a pair of rollers, while the dust contained in it is carried off by the fan. Between the beater and the sieves there is a grid of bars of alternating depth, closed below by a moveable board. The bars of this grid are placed about ⅛in. apart, so as to allow dry leaves and particles of the capsules to fall through.

The fleece is stripped off the sieve cylinders by the rollers G and G_1, and again consolidated and moved forward on a horizontal plate until it is seized by the second pair of feed rollers, C_2 C_3. It then passes through a third pair of feed rollers, C_4 C_5, when it is again dissolved into flakes by the second beater, in the same manner as before. By this beater D_1, the fan F_1, the sieve cylinders E_2 E_3, and the rollers G_2 G_3, the foregoing process is repeated. The fleece then passes between the upper and the two lower calender rollers, H, H_1, H_2, unto the first lap roller, I, being compressed by the solid roller, *h*, which is taken round by contact with the fleece. By the two lap rollers, I and I_1, the cotton fleece, now called lap, is coiled upon the loose roller, K. During the coiling the roller K receives a continual pressure by means of the rack M and the break L.

The machine is put into operation by driving both beater shafts simultaneously from a common pulley on the main shaft. Each beater carries an 8in. pulley, and must make 1,600 revolutions. As the main shaft makes 132 revolutions, the driving pulley must have a diameter of $\frac{1600 \times 8}{132} = 97$ inches.

If a pulley of that size is inapplicable, the velocity-ratio $\frac{1600}{133} =$ 12,1212 must be divided into two factors, say 3,5 and 3,463, and a

shaft counter must be used. If we place on the latter a pulley of $8 \times 3{,}46 = 27{,}7$ inches for driving the beater, and another pulley of 10 inches, the diameter of the main driving pulley will be found $= 10 \times 3{,}5 = 35$in.

$$n = \frac{132 \times 35 \times 27{,}7}{8 \times 10} = 1600.$$

Each beater shaft carries another pulley of 5in. diameter, driving a pulley on each fan shaft of $6\frac{3}{4}$in. The number of revolutions for both fans consequently is

$$= \frac{1600 \times 5}{6{,}75} = 1185{,}2.$$

A third pulley of $4\frac{3}{4}$in. diameter on the shaft of the second beater acts upon a $27\frac{1}{2}$in. pulley on an intermediate shaft, from which all the other revolving parts of the machine receive their motion. For this shaft

$$n = \frac{1600 \times 4{,}75}{27{,}5} = 280$$

It carries, firstly, a pinion with 16 teeth, gearing with a wheel of 63. Connected to the latter is a second pinion of 16 teeth, driving a wheel of 78; fixed to this is a third pinion of 17 teeth, working simultaneously into two wheels of 32 teeth each, one upon each lap roller. These consequently make $\frac{280 \times 16 \times 16 \times 17}{63 \times 78 \times 32} = 7{,}75$ revolutions, having diameters of 9in. each. Their circumferential velocity is $= 9 \times 3{,}14 \times 7{,}75 = 219$ inches.

The intermediate shaft drives secondly the upper callender roller. As already stated, it carries a 16 teeth pinion, gearing with a wheel of 13 teeth; connected with this is another pinion of 14 teeth (the stop pinion), driving the top callender roller by a wheel of 96 teeth. The number of revolutions for the latter is therefore $\frac{280 \times 16 \times 14}{63 \times 96} = 10{,}3707$, while its diameter is $= 6$ inches, and its circumferential velocity $= 6 \times 3{,}14 \times 10{,}37 = 195{,}38$. This callender roller carries a wheel of 24 teeth, working with two others of 20 teeth each, on the lower callender rollers. These consequently make $\frac{10{,}37 \times 24}{20} = 12{,}445$ revolutions; as they are 5 inches in diameter, their circumferential velocity is also

$$5 \times 3{,}14 \times 12{,}445 = 195{,}38.$$

The intermediate shaft further turns the driving cone of the feed regulator. A wheel of 63 teeth on the former acts upon one of 35 teeth on a second shaft, that carries a wheel of 33 teeth driving

another one with 28 on a side shaft. A wheel of 50 teeth is fixed on the latter, gearing with another of 32 teeth on the shaft of the driving cone, which accordingly makes

$$\frac{280 \times 63 \times 33 \times 50}{35 \times 28 \times 32} = 928{,}12 \text{ revolutions.}$$

The top callender roller drives by a wheel of 60 teeth, another of 30 on a side shaft; the latter carries a wheel of 38 teeth, working with another of 28 teeth on the bottom feed roller, C_4 of the third pair. For it,

$$n = \frac{10{,}37 \times 60 \times 33}{30 \times 28} = 24{,}44$$

The top roller, C_5, is taken round by the bottom one by two wheels of 8 teeth each. The diameter of these rollers being 2 inches, their circumferential velocity is $2 \times 3{,}14 \times 24{,}44 = 153{,}48$.

The roller, C_5, carries a pinion with 12 teeth, driving the top feed roller, C_3, of the second pair by a wheel of 19 teeth. The latter therefore makes $\frac{24{,}44 \times 12}{19} = 15{,}43$ revolutions, taking its bottom roller C_2, round by two wheels of 10 teeth each. Both have $2\frac{3}{8}$in. diameter, their circumferential velocity consequently is $= 3{,}14 \times 2\frac{3}{8} \times 15{,}43 = 115{,}07$.

Between the second and third pair of feed rollers therefore a stretching or draught of $\frac{153{,}48}{115{,}07} = 1\frac{1}{3}$ takes place.

The wheel with 10 teeth on the roller C_3, drives by means of a carrier wheel ($t = 50$), a wheel of 14 teeth on the roller G_1, which makes $\frac{15{,}43 \times 10}{14} = 11{,}02$ revolutions.

This 14 teeth wheel takes the roller G round by another wheel of the same size.

In fixed connection with the carrier wheel of 51 teeth is another of 73 teeth, driving one of 170 teeth on the shaft of the sieve-cylinder E_1. The latter makes $\frac{15{,}43 \times 10 \times 73}{51 \times 170} = 1{,}3$ revolutions.

This wheel ($t = 170$) drives by another of 124 teeth the upper upper sieve E, making $\frac{1{,}3 \times 170}{124} = 1{,}78$ revolutions.

The wheel of 20 teeth on the callender roller H, mentioned before, drives by a carrier wheel ($t = 30$), a wheel ($t = 14$) on the roller G_3 n of the latter $= \frac{12{,}445 \times 20}{14} = 17{,}78$. By another wheel of 14 teeth, the roller G_2 receives the same number of revolutions.

The diameter of G_2 and $G_3 = 3\frac{1}{4}$ inches, and their circumferential velocity is $3,14 \times 3\frac{1}{4} \times 17,78 = 181,6$ inches.

Between G_2 G_3 and the callenders, consequently a draught of $\frac{195,38}{181,6}$ and between G_2 G_3 and the lap rollers, one of $\frac{219}{181,6} =$ 1,206 takes place.

Connected to the above carrier wheel, ($t = 30$) is a wheel ($t = 44$,) driving one of 170 teeth on the sieve cylinder E_3, which, therefore makes $\frac{12,445 \times 20 \times 44}{30 \times 170} = 2,147$ revolutions.

The wheel ($t = 170$) drives by another of 124 teeth the cylinder E_2; n for this $= \frac{2,147 \times 170}{124} = 2,943$.

THE FEED REGULATOR.

Pl. IV., *Fig.* 1 to 7.

In the machines without regulators the feed lattice travels with a constant speed of about $\frac{1}{3}$ of the circumferential velocity of the lap rollers; therefore a length of one yard spread on the feed lattice is delivered as three yards of lap.

In order to obtain the lap as uniform as possible, the feed lattice is marked from yard to yard, and upon each yard an equal weight of cotton is placed. A pair of scales is put beside the machine, upon which the attendant has to weigh every time the quantity for each yard. This takes much time, is troublesome, and frequently incorrect, in consequence of the speed at which the feed lattice travels. Besides this, the straps that carry the staves forming the lattice, stretch, consequently the length of the lattice varies.

These drawbacks are entirely removed by Lord's feed regulator.

It is based upon the following principles : the feed lattice is made to travel at a variable speed, namely, in the inverse proportion to the thickness of the layer of cotton between the feed rollers ; so that if this thickness increases, the velocity of the feed lattice grows less, and vice versa.

Before showing how this idea has been carried out, we will consider the mode of transmitting the motion from the driving cone F. By a strap, the rotatory motion is first communicated to the driven cone F, which carries on its shaft a worm a, gearing with the worm-wheel b of 88 teeth, and thus driving the shaft A_2. On the latter three pulleys of $3\frac{1}{4}$in. diameter are fixed, on which the feed lattice straps run. A pinion of 15 teeth on the same shaft, drives by a wheel

of 8 teeth, the feed roller C. The latter drives by an equal wheel of 8 teeth, the top feed roller C. The number of revolutions of the feed rollers is therefore always $\frac{15}{8}$ times that of a shaft A_2.

The two bodies commonly called cones, are, properly speaking, surfaces formed by the rotation of a hyperbola round its axis ; the driving cone is concave, the other convex. As we have seen in the introduction, this mechanism serves to produce a uniformly variable motion, so that with a uniform rotation of the driving cone, the variation in the number of revolutions of the driven cone, produced by shifting the strap, is proportional to the length for which the strap has been shifted.

We here repeat that the two axles must be parallel, that the strap must run always at right angles to these axles, and that the sum of the diameters of the two circles, traced by the centre of the strap on thc cones, must remain the same for every position of the strap.

The diameter of the larger end of each cone is $6\frac{1}{2}$in., that of the smaller one $3\frac{1}{8}$—the sum accordingly $9\frac{5}{8} = 9{,}625$in. The length of the side of the cones is 11in. The cones stand of course reversely opposite one another, and are so placed that the top of the driving and the base of the driven cone are below.

In the lowest position of the strap, n of A_2 is

$$\frac{928{,}12 \times 3\frac{1}{8}}{88 \times 6\frac{1}{2}} = \frac{928{,}12 \times 3{,}125}{88 \times 6{,}5} = 5{,}07$$

in the highest

$$n = \frac{928{,}12 \times 3{,}125}{88 \times 3{,}125} = 21{,}93$$

As the pulleys for the feed-lattice are $3\frac{1}{4}$in. in diameter, or 10,225in. in circumference, the speed of the feed-lattice varies from $10{,}225 \times 5{,}07$ to $10{,}225 \times 21{,}93$, or from 51,83 to 224,2.

The circumferential velocity of the lap rollers is as shewn above, 219in. The lowest position of the strap therefore corresponds to a draught of $\frac{219}{51{,}83} = 4{,}22$, while for the highest position of the strap the draught is $\frac{219}{224{,}2}$ or approximately $= 1$.

The regulator is usually so adjusted, that the draught is $= 3$; i.e , with a standard weight of cotton spread on the lattice and while the strap is in its normal position, three yards of lap are formed from one yard of cotton given upon the feed cloth. We will now determine which position of the strap is the normal one for this draught.

The speed of the feed lattice must according to this draught be $\frac{229}{3} = 73$, therefore the shaft A_2 must make $\frac{73}{19,225} = 7,14$ revolutions. If we call the diameter of a circle traced on the driving cone d and the corresponding one on the driven cone δ, there must be

$$\frac{928,12 \times d}{88 \times \delta} = 7,14 \quad \text{from which}$$

$$\frac{d}{\delta} = \frac{7,14 \times 88}{928,12} = 0,677$$

$$\text{or, } d = 0,677\delta.$$

For every position of the strap we also have $d + \delta = 9,625$;

$$d = 9,625 - \delta$$

By putting those two values of d to equal each other we get

$$9,625 - \delta = 0,677\delta$$
$$\text{or, } 9,625 = 0,677\,\delta + \delta$$
$$9,625 = \delta\,(1+0,677)$$
$$9,625 = 1,677\delta$$
$$\text{and finally } \delta = \frac{9,625}{1,677} = 5,74$$
$$d = 9,625 - 5,74 = 3,885.$$

This diameter must be sought on the driving cone and the circle marked. The normal thickness of the layer of cotton to be fed unto the lattice must now be determined.

If we suppose that one yard of the lap is desired to weigh 1lb., and that the cotton loses 5 per cent. in passing through the machine, then for three yards, 3,15lbs. will have to be spread on the feed cloth. This quantity is exactly weighed and spread as carefully and uniformly as possible on one yard of the feed lattice, and then the machine is started. The top feed roller will be lifted up by the thickness of the layer of cotton, and the distance thus produced between the circumferences of the top and bottom feed roller is the desired normal thickness.

After the feed rollers have thus been placed at their normal distance, the strap is brought upon the place, marked as before on the driving cone.

The hook O_1 at the upper end of the drawbar 0, *Fig.* 2, *pl.* IV., presses upon the bearings of the top feed roller, so that this drawbar participates in the vertical movement of the roller. The bar ends at its lower end in a forked hook O_2 supporting the lever p on both sides, by the projecting edges p_1. The short arm p_2 of this lever rests against the fixed bracket p_3, while the longer one (about twenty times

the length of the other) terminates in an eye p_4. The other end of the feed roller is connected in the same way with a similar drawbar and lever, terminating in a similar eye p_5 *Fig.* 3; p_4 and p_5 are firmly connected by the cross bar p_6. Another rod c_1, is joined with a pin to the centre c of this bar, and has a right hand thread cut upon the other end. Opposite to this is the rod c_3; having at its lower end a left-hand thread. A long nut e couples both screwed ends, by turning which the distance between c_5 and c can be altered. The end c_5 forms a moveable joint with the end of the lever f, that has its fulcrum in f_1 and ends on the other side in a fork f_2, which clips the strap guide for the driving cone. For the purpose of guiding the strap parallel, this strap guide f_3 is connected to that of the driven cone, f_7, by the link $f_5 f_6$, the former swivelling upon f_4, the latter upon f_8.

By turning the nut e therefore, the strap can be moved up or down, and is placed in the before described manner, upon the marked place on the driving cone.

The nut e is kept in its position by the lock-fork c_6, *Fig.* 6.

If the required alteration in the length of $c\,c_5$ is more than the length of the threads permits, the bracket p_3 must be differently adjusted by the screws p_7 and p_8.

The strap will now remain in this position so long as the thickness of the cotton fed on the machine remains the same; if the latter increases, the top feed roller will rise, and with it the points $p_4\,p_5$ and c_5, while $f_2\,f_3$ and f_5 are lowered. The strap will by this means be shifted towards the top of the driving cone, and trace a circle of less diameter on it, while the diameter of the circle traced on the driven cone grows larger; the shaft A_2 and with it the feed lattice will consequently move slower. If, on the other hand, the thickness falls below its normal value, the shaft A_2 will turn faster. If the curves of both cones are properly made, the speed of the feed lattice is in inverse ratio to the thickness of the layer of cotton between the feed rollers, or the product of the thickness of cotton multiplied by the number of revolutions of the shaft A_2 is constant.

If the normal thickness is measured to be 0,5in. while n of A_2 was 7,14, and the speed of the feed cloth was 73 inches, then when the thickness rises to 0,6in., we have the proportion.

$$73 : 0{,}6 :: ? : 0{,}5$$

$$? = \frac{73 \times 0{,}5}{0{,}6} = 61$$

or the feed lattice travels at the rate of 61 inches per minute.

The number of revolutions n_1 of A_2 is found similarly

$$n_1 \times 0{,}6 = 0{,}5 \times 7{,}14$$

$$n_1 = \frac{0{,}5 \times 7{,}14}{0{,}6} = 5{,}95$$

If the cotton has been spread unevenly, so that its thickness on one side is 0,8, and on the other only 0,4, the regulator acts in the same way as if the thickness was evenly distributed $= \frac{0,8 + 0,4}{2} = 0,6$, because the motion of the strap is regulated from the centre of the cross bar p_6.

It is evident from the preceding, that each yard of lap will weigh the same, whatever weight is placed on one yard of the feed lattice. The weighing of the cotton therefore becomes unnecessary, and one workman can easily attend to two machines.

An alteration in the weight of the lap can be effected in two ways, either by altering the normal thickness for the same draught, or by altering the draught.

As regards the first manner, it is evident, that if instead of spreading 3,15lbs. on one yard of the feed lattice for determining the normal thickness, now for instance 5lbs. are put on, (the draught remaining equal three as before, and the cotton losing 5 per cent.) one yard of lap will weigh $\frac{4,75}{3} = 1,58$lbs. Therefore the weight of the cotton required for three yards of lap must first be calculated, then accurately weighed and spread on one yard of the feed lattice as uniformly as possible. The normal thickness being thus accurately produced, the strap is simply guided to the place on the driving cone, which corresponds to a draught $= 3$.

Regarding the second manner, an alteration in the weight of a yard of lap also naturally takes place as soon as a greater or less length of lap is made from the same quantity fed upon the lattice. If, for instance, only two yards of lap are made from the former weight of 3,15 lbs., (the draught being reduced from 3 to 2), one yard of lap will weigh 1½ lbs., instead of 1 lb. as before. In this case the speed of the feed cloth for the normal thickness of the layer of cotton must be one-half of the circumferential velocity of the lap rollers, or $\frac{219}{2} = 109\frac{1}{2}$

By an analogous calculation to the one made above, the diameter of the circle is determined, which the strap must trace on the driving cone in order to impart this speed to the feed lattice. The normal thickness must then be placed between the rollers and the strap put on the calculated circle in the same manner as described before.

To avoid this calculation the strap guide for the driving cone carries a pointer, which indicates on a graduated scale the normal positions of the strap for any draught within the limits allowed by the length of the cones; these limits being as shewn before, 4, 22, and 1.

If the cotton is spread on so thick that the speed of the feed cloth would fall below the lowest limit of 51,83in., the strap drops off the cone.

A few remarks on some of the working parts remain to be added.

The first pair of feed rollers have 2 inches in diameter, or 6,28 inches in circumference. We showed before that their number of revolutions is $\frac{15}{8}$ of that of the shaft A_2. If for a draught of 3 the latter makes 7,14 revolutions, the feed rollers will make $\frac{15}{8} \times 7,14 = 13,4$, and their circumferential velocity will be $6,28 \times 13,4 = 84,15$.

The feed lattice, however, only travels 73 inches, consequently these rollers gain on it 11,15 inches per minute.

The upper callender roller is pressed heavily against the two lower ones. The rod g—*Fig.* 1, *Plate IV.*—is suspended in g_1 from the bearing of the upper roller, and carries the lever g_2, resting with its short arm against the bracket g_3, while the end of the longer arm carries the link g_4. This again supports the lever g_5, the short arm resting against the bracket g_6, and the longer one carrying a weight g_7. The pressure exercised on the roller amounts to 50 cwt.

The two lap rollers I and I_1, turn in the same direction. The roller K lies loosely upon them, and receives its motion by contact. The end of the roller K is kept down by the head M_1 of the rack M, provided with two small friction rollers, i_1 and i_2. The pinion i_3 gears with the rack, and is keyed on the same shaft with the break L. The other end of the roller K is kept down in the same manner by a similar rack and pinion. The break band is connected with the lever L_3, turning on L_2, in such a manner as to be tightened by the weight L_1, supported on the lever. The other arm of the latter finishes in a step board L_4, by treading on which the workman can suspend the breaking action.

STOP MOTION OF THE MACHINE.

If the stopping takes place by guiding the strap upon the loose pulley on the intermediate shaft at the head of the machine, the beaters as well as the fans remain in motion. Besides this the machine has a self-acting stop motion which operates as soon as the coil of lap obtains a sufficient size. The rack M carries a nose k_1, adjustable in a vertical direction by a screw. As soon as the rack is lifted

to a certain point by the thickness of the coil, the nose k_1 strikes against the lever k_2. The latter has its fulcrum in k_3, and its other arm k_4 rests against the pin k_5. This pin forms at the same time the fulcrum for the lever k_6, so that if the nose k_1 lifts the lever k_2 up, these two levers act like one swivelling on k_5. The lever k_6 terminates in a slide piece k_7, resting upon a corresponding slide bracket $k_8^{\prime}$. Upon k_6 being turned, k_7 slides off k_8; this causes the lever k_9, hinged on k_{10}, to drop, and throws the pinion k_{11} out of gear with the wheel k_{12}.

The axle of k_{11} is clipped by a forked bell crank lever k_{15}, having its fulcrum in k_{13}; a downward motion of the axle of k_{11} causes the other end, k_{14}, to move in the direction of the arrow. A rod l which can be adjusted in length by the screw l_7—*Fig.* 7—connects k_{14} with the lower end l_1 of the lever l_2, swivelling on l_3. This lever is connected in l_6 with the lever l_4, which has its fulcrum in l_5. The latter embraces with its other arm, l_7, the shaft of the driven cone, so that a movement of the point k_{14} in the indicated direction causes the worm and worm wheel a and b to become disengaged.

If the machine is stopped in this way, the rollers and the driving cone will remain in motion, besides the beaters and fans. The continuation of the motion of the lap rollers, while the callenders are stopped, causes the lap to break.

SINGLE SCUTCHER.

The lap thus produced is then made more even on a single scutcher. This machine is with a few deviations the same as the second half of the double scutcher. The feed rollers are driven by a side shaft from the upper callender roller at a threefold velocity-ratio. Three laps from the preceding machine are fed simultaneously into this one, so that one yard of fleece taken in by the feed rollers consists of three yards of lap from the double scutcher placed one upon the other. Out of these a new lap of three times the length is formed. The weight of one yard of lap delivered by the single scutcher is consequently equal to the weight of one yard of lap from the double scutcher, less the loss of weight occasioned by the removal of impurities.

The three coils to be fed on the machine are each placed on a bar and put on the feed lattice, one behind the other, so that during the uncoiling the feed rollers are supplied uniformly from all three coils. In the sides of the frame slots are made for these bars, and the three coils are forced by the progressive motion of the feed lattice to turn round the bars.

The width of the machine, *i. e.* the width of the lap to be formed, depends upon the width of the carding engine; both must be the same.

All the other parts, beaters, fans, sieve-cylinders, &c., are exactly the same as in the double scutcher; we therefore think it superfluous to dwell any longer upon this machine.

CARDING ENGINE.

The different objects desired to be attained by carding, are the following:—

1. To place all the cotton fibres, hitherto irregularly crossed in all directions, into parallel positions.

2. To remove completely any impurities that might have remained

3. To remove all fibres which through being too short, would interfere with the strength of the yarn.

4. To form the lap fleece into the sliver or riband necessary for commencing the spinning process.

The ~~first~~ last of these objects is attained by a considerable stretching, *i.e.* extension in a longtitudinal direction. Each unit of the lap is extended to many (say 100,) times its own length, and appears then as a riband of 100 times the length of the original fleece. The proportion of the length of a unit of the lap to the length of the sliver formed from it, is called the draught, being equal to 100 in this case.

The impurities, as dry leaves etc., become fixed between the wire staples of the revolving drums described below, and are removed from time to time by stripping.

The dust as well as the short fibres are forced out by the great circumferential velocity of the cylinder, and fall to the ground.

The formation of the sliver or riband finally is effected by the funnel or trumpet.

There are many kinds of carding engines in use, differing however little from each other. We select for description a double carding engine, as made by Platt Brothers and Co., 48 inches wide on the wires.

a, *Fig.* 1, *Pl.* V., is a roller, which by revolving uncoils the lap fleece put on a bar, so as to be in contact with it; b b_1 are two feed rollers; c the taker in; d the dirt roller; d_1 to d_{10} the rollers; e to

e_4 the clearers; D the back cylinder; and D_1 the front cylinder; E the slow tummer; E_1 the doffer; f the comb; g a web guide; g_1 the trumpet; h and h_1 the back rollers; and i and i_1 the front rollers of the drawbox; k the coiler callenders; m the revolving coiler; l the can into which the slivers are deposited; n the revolving dish by which the can is turned round.

MOTION OF THE VARIOUS PARTS OF THE ENGINE.

There is a fast and a loose pulley of 16 inches diameter, on the shaft of the front cylinder, which must make 150 revolutions per minute. As the main shaft makes 132 revolutions, the driving pulley must have a diameter

$$d = \frac{150 \times 16}{132} = 18{,}18\text{in.}$$

From the front cylinder shaft the back cylinder is driven by two 20in. pulleys, consequently it makes also 150 revolutions. There is another pulley of 20in. diameter on the front cylinder shaft, which drives the clearers e_5, e_6, e_7, e_8, by means of four $7\frac{1}{2}$in. pulleys, making the number of revolutions for each of them

$$n = \frac{20 \times 150}{7{,}5} = 400$$

The clearer e_4 has a pulley of 9in. diameter, and makes consequently $\frac{20 \times 150}{9} = 333{,}33$ revolutions.

In the same manner the clearers e, e_1, e_2, e_3, are driven from the back cylinder shaft at 400 revolutions per minute.

A 12in. pulley on the back cylinder shaft drives a 6in. pulley on the taker-in shaft, n of the latter therefore is $= \frac{150 \times 12}{6} = 300.$

Another pulley of 10in. diameter on the front cylinder shaft drives an 18in. pulley; attached to the latter is a pinion of 36 teeth working into a wheel of 180 teeth on the doffer shaft, for the latter

$$n = \frac{150 \times 10 \times 36}{18 \times 180} = 16{,}666$$

In the same manner the slow-tummer receives 16,666 revolutions from the back cylinder shaft.

A 7in. pulley on the doffer shaft drives the rollers d_6 to d_{10} by means of pulleys of $5\frac{1}{2}$in. diameter, n of these $= \frac{16{,}666 \times 7}{5{,}5} = 21{,}21.$

The rollers d_1 d_2 d_3 d_4 d_5 are driven in the same way from the slow tummer shaft, as well as the dirt roller d, but the latter revolves in the contrary direction.

A bevil wheel of 30 teeth on the doffer shaft gears with another of 40 teeth on a side shaft, on which there is a pinion of 14 teeth (the change wheel) gearing into a wheel of 120 teeth on the bottom feed roller. For the latter,

$$n = \frac{16{,}666 \times 30 \times 14}{40 \times 120} = 1{,}458.$$

The top feed roller is put into motion from the lower one by two wheels of 17 teeth each. The wheel with 17 teeth on the bottom feed roller drives by means of a carrier wheel, another of 48 teeth upon the uncoiling roller; the latter makes therefore $\frac{1{,}458 \times 17}{48} =$ 0,516 revolutions. It must have the same circumferential velocity as the feed rollers, because otherwise the lap would be torn.

The wheel of 180 teeth on the doffer shaft mentioned above drives through a carrier wheel another of 26 teeth on an intermediate shaft, from which the drawbox rollers, callenders, coiler, and can dish receive their motions. For this shaft $n = \frac{16{,}66 \times 180}{26} = 115{,}38$

On this shaft there is, firstly, a wheel of 40 teeth working into another of 30 teeth on the bottom back roller h of the drawbox

$$n = \frac{115{,}38 \times 40}{30} = 153{,}84$$

There is another wheel of 35 teeth on the intermediate shaft, working into one of 24 teeth on the bottom front roller i of the drawbox,

$$n = \frac{115{,}38 \times 35}{24} = 168{,}262$$

The two top rollers h_1 and i_1 (*Fig.* 1, *Pl.* VI.) are pressed down by the weight p and carried round through contact with the bottom rollers.

On the intermediate shaft there is further a wheel ($t = 25$) gearing with another of 20 teeth, to which a mitre wheel of 20 teeth is connected, driving by the other mitre wheel the upright shaft (*Fig.* 1, *Pl.* VI.) from which the callenders and the top and bottom can-motion are worked; for this upright $n = \frac{115{,}38 \times 25 \times 20}{20 \times 20} = 144{,}23$

One of the coiler callenders is driven from it by a pair of mitres of 16 teeth each, and consequently makes also 144,23 revolutions. The second callender is worked from the first by two equal wheels of 24 teeth each.

There is further a pinion of 36 teeth on the upright, driving the coiler, which has 106 teeth, and makes consequently $\frac{144,23 \times 36}{106} =$ $= 48,98$ revolutions.

Lastly, there is a pinion of 8 teeth upon the upright, working into a wheel of 48 teeth; fixed to this is another pinion of 15 teeth, which drives by an intermediate wheel the can-dish. The latter has 120 teeth, and makes

$$\frac{144,23 \times 8 \times 15}{48 \times 120} = 3 \text{ revolutions,}$$

Consequently for each revolution of the can, $\frac{48,98}{3} = 16\frac{1}{3}$ layers of sliver are deposited in it.

The comb f (*Fig.* 1, *Pl.* V.) is worked in the following manner:

A 24in. pulley is fixed upon the front cylinder shaft, and drives another of 4in. diameter on the shaft A. A $5\frac{1}{2}$in. pulley on the latter drives a $3\frac{1}{2}$in. one on the eccentric-shaft B, which therefore makes $\frac{150 \times 24 \times 5,5}{4 \times 3,5} = 1414,3$ revolutions.

The throw of the eccentric is $\frac{3}{4}$in.; it is clipped by the rod c acting upon the lever d, to the other end of which, d_2, the comb f is fastened.

The short arm $d_1 = 2\frac{1}{2}$in. long; the longer arm $d_2 = 3\frac{1}{2}$in.; the fulcrum is in d_0. The comb therefore makes for each revolution of the shaft B an up and down stroke of

$$\frac{\frac{3}{4} \times 3\frac{1}{2}}{2\frac{1}{2}} = 1,05 \text{ inches.}$$

All the rollers marked b c d e D and E (*Fig.* 1, *Pl.* V.) are covered with cards. These consist of a strong cotton cloth, thickly covered with fine wire staples, that are ground sharp, and have a length of 0,4in. The staples or teeth form an angle of 20 to 30 degrees with the radial direction. Those of the rollers marked b_1 d D and D_1 turn in the same direction as the unlapping roller a; all the others in the contrary way. The wire staples of the cards incline in the same direction as the rollers revolve on those marked b c d D D_1 and e to e_8, so as to advance them; on the others they incline in the opposite sense to the direction in which the rollers turn. The space between the feed rollers and the doffer is closed in by covers on all sides so as to prevent the cotton from flying off. The covering on the top consists of 4 lids that can be opened on both sides of the cylinders, and kept in this position by the hooks o and the pins o_1 (*Fig.* 3, *Pl.* VI.)

A bottom of sheet iron extends below the whole of the rollers, except below the two cylinders, where it consists of a grid of triangular wooden bars, so as to allow the dust and separated short fibres to fall through. This bottom enclosure fits on its entire length closely to the rollers above.

The rollers c d to d_5 and e to e_3 are placed so close to the back cylinder as just to miss touching it; the same takes place between the rollers d_6 to d_{10}, e_4 to e_8, and the front cylinder D_1; e_4 being simultaneously in the same position to the slow-tummer E.

The same distance must be kept between each roller and the clearer belonging to it; for instance, between e and d_1, e_1 and d_2, &c., while e_3 has to work close to d_4 and d_5 at the same time, and e_5 to d_6 and d_7.

In order to allow the rollers to be brought so close to one another, the bearings of all the clearers are adjustable in a radial direction, and those of the rollers d in this and a tangential direction as well. *(Pl. VI, Fig. 4.)*

To enable us to follow the carding process, we will put the circumferential velocities of all the various drums and rollers together: n is the number of revolutions given above; d the diameter; u the circumference $= d \times 3{,}14$, and $v = n \times u$, the circumferential velocity.

	n	d	u	v
a	0,516	5,64	17,72	9,14
b b_1	1,458	2	6,28	9,156
c	300	9,5	29,84	8952
d - d_{10}	21,21	7	22	466,4
e - e_8	400	4	12,57	5100
e_4	333,33	6	18,85	6283,27
D *and* D_1	150	40	125,666	18849
E	16,666	27	84,82	1413,1
E_1'	16,666	22	69,11	1151,37

The feed rollers convey a length of 9,156 inches of lap fleece to the machine, the taker-in seizes the cotton with its wire staples, and by its circumferential velocity extends the above length of fleece to 8952 inches. The cards of the back cylinder then takes the cotton from the taker-in, whereby the length of the fleece is extended to 18849 inches. After this the cotton is caught up by the wires of the dirt roller, runs round it, and is brought back to the cylinder; therefore, first a shortening, and then a stretching takes place—the length being reduced to 466,4 inches, and immediately after extended

again to 18849 inches. The wires of the dirt roller meeting those of the cylinder, with their points inclined against them, the impurities (parts of the covering of the seeds, &c.) are fixed amongst them, and thus separated from the cotton. The same is done by both drums, in consequence of the inclination of their staples.

The cotton then passes under the clearer e without adhering to it, as can be seen from *Fig.* 8, *Pl.* IV., but is taken from the cylinder by the roller d_1 and from this by the clearer e, from which it returns again to the cylinder D. It then passes over d_2 and e_1 and back upon the cylinder. The same operation is repeated several times, till the cotton is at last removed from the doffer E_1 by the comb. By these frequent changes in the longitudinal extent of the fleece, measuring originally 9,14 inches, the fibres are combed or brought into parallel positions.

The cotton when combed off the doffer appears as a thin fleece and is led over the guide g, and through the trumpet g_1, *F*ig. 1, *Pl.* VI, into the draw-box. Between the front and the back rollers of the latter it is stretched or drawn. For the rollers hh_1 is

n	d	u	v
153,84	$1\frac{3}{4}$in.	5,497	845,45

for $i\,i_1$—

168,262	2	6,28	1056,67

The draught accordingly is $\frac{1056,67}{845,45} = 1\frac{1}{4}$.

To keep the sliver tight between the front draw-box rollers and the coiler callenders, the latter must gain a little over the former; *i. e.*, their circumferential velocity must be somewhat larger, say 12 inches per minute. The number of revolutions for the callenders we found to be 144,23; if v for them is to be $1056,67 + 12 = 1068,67$, their diameter must be

$$\frac{1068,67}{144,23 \times 3,1415} = 2,36 \text{ inches.}$$

The riband now passes through the coiler m, *Fig.* 1, *Pl.* VI, into the can. The coiling disc carries a short oblique tube passing through it, the upper opening of which lies in the centre of revolution of the disc, while the lower one is at a distance equal to $\frac{1}{4}$ of the diameter of the can, measured horizontally, so that in revolving it describes a circle between the circumference and the centre of the can. If the can has a diameter of 9 inches, the horizontal distance between the upper and lower opening will accordingly be $\frac{9}{4} = 2,25$ inches.

Let A, *Fig.* 2, *Pl.* VI, be the centre of the can ($\frac{1}{4}$ size); A C its radius, $= 4{,}5$ inches; B the centre of the coiler, and the dotted circle the way described by the centre of the lower opening in the coiler in revolving round B. If the centre stands at first in A, it gets in half a revolution to C, where it would touch the inside of the can, if the latter was standing still. But during half a revolution of the coiler, the can turns $\frac{1}{2 \times 16{,}3}$ and as its circumference is $3{,}14 \times 9 = 28{,}26$ inches, the point C moves $\frac{28.26}{32{,}6} = 0{,}867$in., and gets to C_1. If we draw a diameter through B at right angles with A C, cutting the dotted coiler circle in D, and draw a line through A and D, it will intersect the circumference of the can in a point E. We then cut a piece $E E_1$ off on E C, equal $\frac{0{,}867}{2}$, draw $A E_1$, and strike a circle round A with the radius A D, intersecting $A E_1$ in D_1. In the same way we draw A F, and elongate it to G; cut on the circumference of the can a piece $G G_1 = \frac{3}{4} \times 0{,}867$ off and draw $A G_1$ intersecting the circle struck round A with $A F = A D$ in the point F_1. Then A, D_1, C_1, F_1 are four points of the figure in which the sliver is deposited. $A C_1$ is the smallest, and $F_1 D_1$ the largest diameter of this figure which takes the shape of a curve passing through these four points.

By the revolutions of the coiler the sliver obtains a small twist of 48,98 turns on 1068,67 inches length, or one turn for every 21,82 inches.

To avoid the rapid wear of the draw-box rollers, by having the riband always running in in the same place, the trumpet is slowly moved to and fro (travelling motion). It slides between two slide-bars, and is connected to the lever h_1 in *l*, *Pl.* IV, *Fig.* 9. This lever swivels on *k*, and has a slot *g*, in which the pin *f* slides in revolving round the centre *e*. For each revolution of the shaft *e*, the trumpet consequently makes one front and back stroke $= l\,l$. The pin is shown on the drawing in the position at which the stroke begins; $fl = fk$, $ef = \frac{1}{2}$ inch, therefore $l\,l = 2$ inches.

Tne shaft *e* is turned in the following manner: a worm on the shaft *h* works into a worm-wheel *b*; fixed to this is a pinion *c*, gearing with the wheel *d*—the pin *f* is fixed in the latter.

This travelling of the sliver is another reason why the coiler callenders must have a greater circumferential velocity than the drawbox rollers $i\,i_1$. The callenders are slightly inclined against the longitudinal axis of the machine, so that the sliver runs at a right angle into them when the trumpet is in its middle position.

Lately the bottom below the front cylinder has been formed by a sheet-iron sieve (similar *Fig.* 7, *Pl.* II), instead of the grid; so that the short fibres are taken up again, and only the dust falls through. This is an improvement in an economical point of view, but detrimental to the quality of the yarn.

The cards are numbered according to the number of wire staples or teeth on a square inch. For middle numbers of yarn (24 to 60) the suitable numbers of the carding cloth are: for the taker-in No. 70; for the dirt-roller *d* No. 60; for the back cylinder, the appertaining rollers and clearers, and the slow-tummer, No. 90; for the front cylinder, its rollers and clearers and the doffer, No. 110.

The grinding of the teeth best takes place every day, but must be done at least twice a-week; there are moveable bearings above the cylinders and doffers into which the glazing roller, covered with emery, is placed. The slow-tummer and doffer have separate pulleys for the purpose of grinding, and only the parts to be ground and the glazing rollers are turned in the direction the doffer turns in, when the engine is working. The rollers and clearers are taken out and ground on a separate machine.

Besides this the cylinders have to be cleaned several times a day. For this purpose they are slowly turned round by hand in the opposite direction to that in which they run when working, while at the same time one of the clearers is turned in its usual direction. The impurities pass from the cylinder upon the clearer, and from the latter upon the appertaining roller by turning the same round, from which the dirt is easily removed. The frequent repetition of this cleaning process contributes greatly to the evenness of the produce.

The draught of this carding engine is $\frac{1068,67}{9,15} = 116,79$.

The slow-tummer and doffer can be thrown out of gear. In this case only the cylinders, taker-in and clearers revolve.

Two alterations can be made in this machine, firstly, in the length of sliver turned out per minute, and secondly in the draught.

1. The length of the riband delivered per minute depends in the first place upon the circumferential velocity of the callenders, and this again upon the speed of the doffer shaft, from which, as we have shown above, the callenders are driven. By substituting for the pinion with 36 teeth for the doffers, others with 35 teeth, the circumferential velocity of the callenders will be

$$v = \frac{150 \times 10 \times 35 \times 25 \times 2,36 \times 3,14}{20 \times 18 \times 26} = 1039,04$$

The draught necessarily remains the same as before, because the circumferential velocity of the feed rollers has been changed in the same proportion by altering the pinion for the slow tummer. For the feed rollers we now find

$$v = \frac{150 \times 10 \times 35 \times 30 \times 14 \times 2 \times 3{,}14}{18 \times 180 \times 40 \times 120} = 8{,}9$$

The draught consequently is

$$\frac{1039{,}04}{8{,}9} = 116\tfrac{3}{4}$$

Less lap is worked up in this case and less sliver turned out.

In the following table, the lengths in inches of the sliver delivered per minute with different pinions are put together.

Number of Teeth.	Length of Sliver.
32	950
33	979,67
34	1009,35
35	1039,04
36	1068,67
37	1098,42
38	1128,11
39	1157,79
40	1187,48

The shorter the delivered length is, the better the various objects of the carding process are naturally attained, it therefore depends upon the quality and thickness of the yarn to be spun, how far the carding engine can be tasked.

2. An alteration in the draught is made by changing the pinion with 14 teeth for the feed rollers. By doing so, the circumferential velocity of the feed rollers and its ratio to that of the callenders is altered, this ratio being the draught.

By taking a pinion of 15 teeth, v for the feed rollers becomes

$$v = \frac{150 \times 10 \times 36 \times 30 \times 15 \times 2 \times 3{,}14}{18 \times 180 \times 40 \times 120} = 9{,}81$$

The draught is therefore $\frac{1068{,}67}{9{,}81} = 108{,}93$.

In the following table the values of v and the draught for different pinions are placed together.

t	v	draught.
10	6,54	163
11	7,194	148
12	7,848	136
13	8,502	125½
14	9,156	116¾
15	9,81	109
16	10,464	102
17	11,118	92
18	11,772	90½

By altering the draught the weight of the sliver per yard is altered.

Supposing for instance, a yard of the lap used to weigh 1lb. = 7000 grains, and 4 per cent. to be lost in carding, then with a draught of 116¾ a length of 116¾ yards of sliver will weigh 6720 grains, consequently ¼ ley = 30 yards 1926,76 grains.

If we now put a pinion with 17 teeth on, instead of the one with 14, we obtain from one yard of lap 96 yards of sliver according to the above table. These will weigh the same as the 116¾ yards obtained before, viz., 6720 grains, so that in this case ¼ ley weighs 2100 grains.

The first alteration regarding the length of sliver delivered per minute is only made in first putting the machine to work, when the carding engines are so adjusted as just to supply the drawing and slubbing frames in use.

The draught is seldom changed in practice; instead of doing so it is generally preferred to alter the weight of the lap, if another number of yarn has to be spun.

Messrs. Platt, Brothers, & Co., have lately introduced Ashhead's patent self-stripping apparatus to their carding engines, by which the stripping or cleaning is effected by the engine itself, thus saving time and improving the action of the cards.

In using double carding engines one carding is sufficient up to No. 80, and with single carding engines up to No. 60. For higher numbers the carding process must take place twice.

The first carding is done in the manner described before; however, instead of bringing the sliver to the drawing frame, a number of

slivers are united again into a lap by the Derby doubler, and this is again subjected to the carding process.

Although this second carding might be done on the same engine, two sets are always used, called breaker and finisher carding engines. They are usually alike, although frequently a finer number of the carding cloth is employed for the finisher than for the breaker.

For this repeated carding the double carding engines as described are not used, but always two single ones.

In spinning numbers of yarn between 60 and 80, either one double carding engine. or breaker and finisher engines may be used. The former is preferable on account of cheapness, if no finer yarn than No. 80 is spun in the mill.

We omit the description of the Derby doubler, as this work only treats of the manufacture of coarser yarns than No. 80.

DRAWING FRAME.

This machine serves to make the ribands or slivers obtained from the carding engine even, by uniting or doubling a number of them, and then drawing them to about as many times their original length as the number of doubled slivers amount to. The evenness would be perfect, if the web so formed contained the same number of fibres in each cross section of its entire length, but it is quite sufficient if this evenness is approximate. It will the nearer approach perfection, the oftener the doubling and stretching of the ribands is repeated.

For spinning No. 20 to 60, generally six slivers are united into one, and this stretched to six times its length. Six of these webs from the first box are united and stretched as before, and by uniting again the same number of webs from the second box, and drawing them in the same manner, the web received from the last box is ready for slubbing.

For higher numbers eight slivers are united into one, and this stretched to eight times its length; this operation is repeated four or five times.

We select for consideration in the following pages, a frame of three boxes, by each of which six slivers after being united are stretched to six times the original length of each of them, or, as it is usually termed, whose draught is six.

If we take a sliver, 18 yards in length, from the engine head, cut it into six equal lengths, and count the number of fibres contained in each cross cut, we shall find them to differ. Suppose we found in the

1st cross cut	12000	fibres.
2nd „	10000	„
3rd „	14000	„
4th „	10000	„
5th „	8000	„
6th „	6000	„
	60000	„

By dividing this number by six, we find the average number of fibres in the cross cut equal to 10000. This will also be the number of fibres contained in each cross section of the web from the last box, because those 18 yards are always folded into a length of three yards, and afterwards stretched to 18 yards.

If we cut the six slivers after they are doubled, but before they are drawn, in any place, the total number of fibres in this cross section ought to be 60000. Suppose five of these slivers contain at that point 10000 fibres each, but the sixth only 8000, then we should have a deficiency of 2000 fibres or of $\frac{2000}{10000} = \frac{1}{5}$ of the right number in this sixth sliver; considering the whole cross section of the doubling however, the deficiency would be $\frac{2000}{60000} = \frac{1}{30}$ of the proper number. The drawing does not influence the deficiency, so that after this operation $\frac{1}{30}$ of 10000 or $333\frac{1}{3}$ fibres will be wanting in the same spot; the cross cut of the web will consequently contain $9666\frac{2}{3}$ instead of 10000. The deficiency, which was $\frac{1}{5}$ in the sliver from the engine head, is in the web from the first draw box reduced to $\frac{1}{30}$, or to $\frac{1}{6}$ of its original amount. By putting this web together with five others containing the right number of fibres, the cross cut will contain 59666 fibres instead of 60000, the deficiency being $\frac{333}{60000}$ or $\frac{1}{180}$, and after the stretching $\frac{1}{180}$ of $10000 = 52\frac{1}{2}$ fibres will be wanting. The web from the second box therefore contains in this place $9945\frac{1}{2}$ fibres instead of 10000; the deficiency has again grown six times less.

By repeating the doubling and drawing we obtain from the last box a web, the deficiency of which will again be six times less or $\frac{1}{1080}$ of the original; the number of fibres will be $\frac{10000}{1080}$ less than 10000, or,

$$10000 - 9 = 9991.$$

We have always supposed that the slivers, folded together with the deficient one, contained the right number of fibres. In reality this will never be the case, still we shall be right in saying that any defect or irregularity will be diminished to $\frac{1}{6}$ of the amount as many times as doublings take place; in our example it will be reduced to $\frac{1}{6\times6\times6}=\frac{1}{216}$ of the original deficiency.

If we alter the draught from 6in, to 7, we obtain out of the 18 yards of sliver from the engine head, 21 yards of web from the first drawbox. The average number of fibres in any cross section will be $\frac{60000}{7}=8714{,}3$: the deficiency resulting from the deficient sliver will be in the same manner $\frac{1}{30}$ of $8714{,}3=290{,}5$ and the number of fibres in that point only 8423,8.

If we thus diminish the number of fibres for the standard cross section by increasing the draught, we obtain a greater length, but at the same time the weight per yard naturally becomes less.

Supposing the 18 yards of sliver from the engine head, weigh 100 grains or $\frac{100}{18}=5{,}555$ grains per yard, then each yard of web from the last box will weigh the same, if the draught be six, But if the draught is altered to seven in each box, then the 18 yards from the engine head, will turn out as $28\frac{1}{2}$ yards of web from the last box; the weight per yard in this case will be

$$\frac{100}{28{,}5}=3{,}51 \text{ grains.}$$

We now pass to a description of a drawing frame, as made by Parr, Curtis, and Madely.

This machine consists of three separate parts, the three heads, resting on a framing and driven by a driving shaft common to all three; each of them however, can be worked and stopped independently of the others. They are all alike, differing only in the position they are placed in; it will therefore be sufficient to describe one of them.

The driving shaft must make 240 revolutions per minute, and carries a 15in. pulley. As the mainshaft makes 132 revolutions, the pulley on it must have a diameter of

$$\frac{240\times15}{132}=27{,}27 \text{ inches}$$

There is another pulley of 18in. diameter on the driving shaft, working the front roller, *Fig.* 3, I. *Pl.* V, by a pulley of 11in. diameter, the roller consequently makes

$$\frac{240\times18}{11}=392{,}7 \text{ revolutions.}$$

The front roller carries a pinion of 24 teeth driving a stud wheel of 86 teeth which is connected to a wheel of 34 teeth (the change wheel) driving the backroller IV by a wheel of 57 teeth. The back-roller therefore makes

$$\frac{392,7 \times 24 \times 34}{86 \times 57} = 65,37 \text{ revolutions.}$$

The second and third roller II and III are placed between the front and backroller, and are both driven from the back roller. A wheel of 46 teeth on the latter works by a carrier-wheel a wheel of 16 teeth on the second roller, which consequently makes

$$\frac{65,37 \times 46}{16} = 187,94 \text{ revolutions.}$$

A second wheel of 30 teeth on the backroller, works by a carrier wheel the wheel of 20 teeth on the third roller, the latter accordingly makes $\frac{65,37 \times 30}{20} = 98$ revolutions.

These four rollers are of iron and fluted, above each of them another roller, (top roller) covered with leather is placed, and pressed by a weight against the bottom roller, thus forming four pairs. The distance between every two of these pairs depends upon the length of the staple of the cotton; for this reason their bushes are movable in the horizontal direction.

In the following table we signify by

n the number of revolutions of the roller.
d the diameter ,,
u the circumference ,,
v the circumferential velocity ,,
D the draught between two pairs of rollers.

Roller	*n*	*d*	*u*	*v*	D
I.	392,7	$1\frac{1}{4}$	3,927	1542,13	2,613
II.	187,94	1	3,14	590	1,917
III.	98	1	3,14	307,7	1,198
IV.	67,37	$1\frac{1}{4}$	3,927	256,7	

The whole draught between the four pairs is $\frac{1542,13}{256,7} = 6,0075$ the same number is of course obtained by multiplying

$$2,613 \times 1,917 \times 1,198.$$

A pair of callender rollers V and VI, *Fig.* 2, *Pl.* IV. take in the web delivered by the front roller. The latter carries a pinion of 18

teeth, driving by a carrier wheel, another of 43 teeth on the callender V, which consequently makes

$$\frac{392{,}7 \times 18}{43} = 164{,}386 \text{ revolutions.}$$

The other callender is driven from this by two equal wheels of 24 teeth each, and makes therefore the same number of revolutions. The diameter of the callenders is three inches, consequently $u = 3 \times 3{,}14 = 9{,}42$ and $v = 164{,}386 \times 9{,}42 = 1548{,}516$. The callenders gain on the front roller 6½ inches per minute, or 1 inch in 237,23 inches. The whole draught of the frame is thereby increased from 6,0075 to 6,0324, being now $\frac{1548{,}5}{256{,}7}$

For one delivery the back roller takes in $6 \times 256{,}7 = 1540{,}2$ inches of sliver per minute; the callenders deliver in the same time 1548,5 inches, or 8,3 inches more. If the box had three deliveries, these will be an accumulation of $3 \times 8{,}3 = 24{,}9$ inches of web per minute, between two boxes. This accumulation is required for working the second box without interruption when the first one stops for a moment.

After passing the callenders the web is lead through a tube in the revolving disc or coiler into a revolving can, just in the same manner as described with the carding engine.

The coiler is driven in the following way:

The 18 teeth pinion on the front roller drives by two carrier wheels a wheel of 47 teeth on a horizontal shaft, and the latter drives another shaft by two mitre wheels of 28 teeth. The other end of this shaft carries a wheel of 42 teeth acting upon the coiler, which has 68 teeth. It makes therefore

$$\frac{392{,}7 \times 18 \times 28 \times 42}{47 \times 28 \times 68} = 9{,}29 \text{ revolutions}$$

The aforementioned mitre wheel of 28 teeth on the horizontal shaft, drives by another mitre wheel of 28 teeth an upright, on the lower end of which a pinion of 8 teeth is keyed on, gearing with a wheel of 58 teeth; a pinion of 23 teeth is connected with the latter, and drives by a carrier wheel the dish on which the can is placed; this dish has 100 teeth. The number of revolutions of the can consequently is

$$\frac{392{,}7 \times 18 \times 28 \times 8 \times 23}{47 \times 28 \times 58 \times 100} = 4{,}77$$

Generally each box has three deliveries. The rollers and callenders are common to all three, and the same horizontal shaft drives the

three coilers, but there is only one upright shaft for the can-motion of the centre delivery, the two other can-motions being driven by carrier wheels from the former.

The front and back stop motion are further to be noticed, the latter for stopping the box if one of the slivers breaks, the former for doing the same if the web after passing the rollers is not taken in by the callenders. Each of the six slivers is led into the back rollers through a guide *a*, *Fig.* 3 and 4, *Pl.* V.; after passing the four pairs of rollers, the web is led through another web guide between the callenders. All these guides are constructed as levers swiveling on studs and balanced in such a way, that the upper part is kept down by the weight of the sliver running through it; as soon as the latter breaks, the other end of the lever falls down.

The shaft *c*, *Fig.* 3 and 4, *Pl.* V. is driven from the back roller by the wheel *d*, making 45 revolutions. On *c* a roller *h* with eight furrows, called the spider, is fastened, which stops the revolving motion of *c* as soon as one of the levers drops down into a furrow of the spider. The wheel *d* runs loose on the shaft *c* and is kept in its place by the nut *e*. The boss *f* is connected with the said shaft by a feather and groove, allowing it to slide on it. The boss as well as the wheel are furnished with clutches or teeth, which pressed into each other form a catch-box. While they are engaged the wheel will take the boss round, and the latter the shaft *c*, but as soon as the motion of the shaft is stopped, the boss cannot follow the revolutions of the wheel; the clutches begin to slide upon each other and the boss is pushed back, compressing the spring *g*.

The lever *h* turns on a stud h_3 and carries at one end a projecting piece, that slides against the skew underside of the flanch, forming the clutches of the boss *f*, while the latter is in catch, and is depressed by the flanch when the boss moves backwards. The other end h_2 of the lever, *Fig.* 4 and 7, *Pl.* V. fits into a notch of the rod *i*, which has a tendency to move in the direction marked by the arrows in consequence of the spring *k*, one end of the latter being fastened to *i*, and the other to the machine frame. When the lever is lifted out of the notch by the depression of its other end h_1, the rod slides in the indicated direction; and as it carries on one end the strap guide I, the strap is shifted from the driving pulley I_1 upon the loose pulley I_2. The other end of the rod *i* slides in the bracket i_1 and the length of its travel is limited by the two pegs i_2 and i_3 stopping against this bracket.

For the purpose of stopping the box by hand, the rod *l* is moved by a handle in the direction shewn on the drawing. The end l_1 being cut off in a slanting direction, acts upon the lever h_2 and lifts it out of the notch, when the rod *i* begins to slide and stops the box.

As stated before, the draught in each box of the frame is 6,03, which means to say that $\frac{1}{4}$ ley = 30 yards of sliver from the carding engine head will be turned out as 30,452 yards of web from the last box, or if the weight of $\frac{1}{4}$ ley of sliver from the engine head be $\frac{1}{2}$ oz. = 240 grains, the same length of web from the last box will weigh 236,44 grains. If the weight of the web from the last box requires altering, the draught must be altered by changing the change wheel of 34 teeth.

Supposing we take a wheel of 30 teeth instead, the back roller will then make

$$\frac{30 \times 392,7 \times 24}{86 \times 57} = 57{,}678 \text{ revolutions}$$

As its circumference is 3,927, it will take in a length of 392,7 × 57,678 = 226,5. The speed of the front rollers and callenders remaining unaltered, the draught will be

$$\frac{1548{,}5}{226{,}5} = 6{,}836.$$

If we now take again a length of 30 yards of sliver from the engine head, folded together into a length of five yards, the first box will deliver 5×6,836=34,180 yards. For finding the length of web from the second box, we have the proportion

$$34{,}18 : ? :: 30 : 34{,}18$$

$$? = \frac{34{,}18 \times 34{,}18}{30} = 38{,}94.$$

and again for the length of the web from the last box

$$38{,}94 : ? :: 30 : 34{,}18$$

$$? = \frac{38{,}94 \times 34{,}18}{30} = 44{,}366.$$

These 44,366 yards of web from the last box have the same weight as 30 yards of sliver from the engine head; if the weight of the latter is 240 grains as before, $\frac{1}{4}$ ley from the last box will weigh

$$\frac{30 \times 240}{44{,}336} = 162{,}28 \text{ grains.}$$

The following table shows the draught and the length of sliver

in inches, taken in per minute by the backroller for different change wheels.

Number of teeth of change wheel.	Draught.	Length of Web.
30	6,836	226,5
31	6,62	233,91
32	6,41	241,46
33	6,22	249
34	6,03	256,7
35	5,86	264,09
36	5,70	271,64
37	5,54	279,18
38	5,40	286,73

The weight of the web is in direct ratio to the number of teeth of the change wheel, and in inverse ratio to the draught.

If an alteration in the weight of the web from the last box is to be made while the frame is working, the following rule will show how to find the required change wheel.

"Find the exact weight of ¼ ley of web from the last box by weighing the same. Multiply the desired weight of ¼ ley by the number of teeth of the change wheel then working, and divide the product by the actual weight of ¼ ley found before. This gives the number of teeth for the change wheel, which will turn out web of the desired weight."

Example:—Suppose the weight of ¼ ley is found to be 200 grains, the change wheel having 34 teeth. What must be the number of teeth for the change wheel, producing web of 225 grains to ¼ ley.

$$t = \frac{225 \times 34}{200}$$

```
      225
       34
      ---
      900
     675
200) 7650 ( 38,25
     600
     ----
     1650
     1600
     ----
      500
      400
     ----
     1000
     1000
```

being next to 38 teeth.

The number of teeth may also be found by multiplying the actual weight 200, by the draught of the wheel of 34 teeth, and dividing the product by the required weight 225, and then taking the wheel corresponding to the draught thus obtained from the table.

$$\frac{200 \times 6,03}{225}$$

$$\begin{array}{r} 6,03 \\ \underline{200} \\ 225)\overline{1206,00}(5,36 \end{array}$$

being near to 5,40 in the table. This likewise gives a wheel of 38 teeth.

If the change to be made is very small, the stud wheel of 86 teeth may be changed instead of the change wheel; as this has a large circumference it will produce a less alteration.

It will easily be noticed that the most advantageous draught is 6,03, the change wheel having 34 teeth; because in case the draught is less, one box will have to wait for the preceding one, and if it is more, a large accumulation of web will soon take place between every two boxes. The desired alteration in the weight is therefore better made on the lap machine.

The second box is generally so placed, (always in small concerns, that have only one frame), that its back roller is on the same side of the frame with the front rollers of the first and third box. The change wheel is usually alike for all three boxes, thus making the draught the same in each box.

SLUBBING, INTERMEDIATE, AND ROVING FRAMES.

The web, delivered by the drawing frame, is now brought in the can to the slubbing frame. Here it is first drawn by three pairs of rollers, and after receiving a certain number of twists by a spindle, it is wound upon a bobbin.

Two of these slubbings are united on the intermediate frame, again drawn by rollers, and after receiving their twist, wound upon a bobbin. The same process of doubling, drawing, twisting, and winding on, is repeated on the roving frame; and the rovings thus obtained are ready for being finished (spun) on the mule or throstle.

Taking the above-mentioned doubling not into account, the roving delivered by the intermediate frame is finer than that from

the slubbing frame, in consequence of its being drawn again. The ratio between the length of thread wound on and the number of revolutions of the spindles, is greater in the intermediate than in the slubbing frame; and as the former machine is driven at a greater speed than the latter, a spindle of the intermediate frame does not only turn a greater length of roving, but the latter also obtains more twists per unit of length.

From the same reasons the roving frame turns out finer and more twisted rovings than the intermediate frame. To the number of twists the intermediate frame gives to the slubbing, those received before on the slubbing frame, divided by the draught of the intermediate frame, have to be added; in the same way to the number of twists received on the roving frame, those already imparted by the intermediate frame, divided by the draught of the former, have to be added.

The spindles for all three machines are constructed in the following manner. *Fig.* 4, *Pl.* VIII.

x is the spindle, y the bobbin turning loosely on it; x_1 the flyer, consisting of a tube and two hollow legs, firmly connected with the spindle so as to share its rotatory motion; z is the presser or finger, having its bearing at z_1 round the leg, and surrounding it also at z_2. It turns freely on its bearing z_1, and presses in consequence of the quick rotation of the spindle and the resistance of the air against the bobbin. The other leg carries a similar presser. The slubbing is introduced into the tube of the flyer x_2, and comes out of it at x_3, it is then entered into one of the legs at x_4, which it leaves at x_5; when it is passed several times round the presser, and finally brought upon the bobbin through the hole z_3.

The spindles and drawing rollers of a frame are always driven at a constant speed, so that for every minute the same length of slubbing is led into the spindle, and receives the same number of twists for each unit of length.

Supposing the bobbin to remain stationary, then for one turn of the spindle a length of thread will be wound on the bobbin equal to its circumference. If the spindle makes $\binom{n}{s}$ revolutions per minute, the length of thread wound on during this time would be $\binom{n}{s}$ times the circumference of the bobbin. If we call this length l, and the circumference of the bobbin u, we have $l = \binom{n}{s} \times u$.

If the bobbin now were turned $\binom{n}{s}$ times in the same direction as the spindle, the thread wound on would be unwound again; therefore when spindle and bobbin are turned the same number of times in the same direction, the length of thread wound on would be $= o$.

But if the bobbin makes a less number of revolutions per minute than the spindle, which we will call (n_b), then the length of thread wound on during this time will be

$$L = u \times [(\tfrac{n}{s}) - (\tfrac{n}{b})]$$

Or, as u is $= 3{,}14\ d$, the diameter of the bobbin being d,

$$L = 3{,}14\ d \times [(\tfrac{n}{s}) - (\tfrac{n}{b})] \ldots\ldots 1.$$

If the bobbin and flyer always retained their mutual position, the thread would be always wound upon the same spot. In order to cause the thread to be wound on spirally, so that one lies at the side of the other, the bobbin slides on the spindle, till the wound-on thread has nearly reached the end of the bobbin, when its motion is reversed so that the bobbin slides in the opposite direction, and a second layer of thread is placed on the top of the first.

For the second layer, therefore, the diameter of the bobbin has increased by 2δ, if we call the thickness of the thread δ, but as the thread of the second layer will fit partly in the hollows between the threads of the first layer, and as the thread is besides compressed by the pressure of the two fingers, so as to obtain an elliptical section, the effect upon the second layer is only as if it had increased by δ.—See *Fig.* 2, *Pl.* VIII.

The equation is consequently for the second layer,

$$L = 3{,}14\ (d + \delta) \times [(\tfrac{n}{s}) - (\tfrac{n}{b})] \ldots\ldots 2.$$

The one factor on the right side has grown larger, therefore as L must remain the same, the other, *i. e.* $(\tfrac{n}{s}) - (\tfrac{n}{b})$ must grow less, or as $(\tfrac{n}{s})$ is constant, $(\tfrac{n}{b})$ must increase.

If we call this new value of $(\tfrac{n}{b})$ now $(\tfrac{n_1}{b})$ the equation 2 will be

$$L = 3{,}14\ (d + \delta) \times [(\tfrac{n}{s}) - (\tfrac{n_1}{b})]$$

$$L = 3{,}14\ (\tfrac{n}{s}) \times (d + \delta) - 3{,}14\ (\tfrac{n_1}{b}) \times (d + \delta)$$

$$3{,}14\ (\tfrac{n_1}{b}) \times (d + \delta) = 3{,}14\ (\tfrac{n}{s}) \times (d + \delta) - L$$

$$(\tfrac{n_1}{b}) = (\tfrac{n}{s}) - \frac{L}{3{,}14 \times (d + \delta)} \ldots\ldots (3)$$

After the second layer is filled, the bobbin again turns back, and its diameter increases again by δ for the third layer; n therefore must also increase again, and we find for the third layer

$$\left(\frac{n}{b}{}^{2}\right) = \left(\frac{n}{s}\right) - \frac{L}{3{,}14\ (d + 2\ \delta)}\ \cdots\cdots\cdots\ 4$$

It follows in the same way for the $(x + 1)$ th layer,

$$\left(\frac{n}{b}{}^{x}\right) = \left(\frac{n}{s}\right) - \frac{L}{3{,}14\ (d + x\ \delta)}\ \cdots\cdots\ (5)$$

This equation (5) therefore gives the numbers of revolutions of the bobbin for each layer of thread.

The value of d changes for every layer by the same amount δ, the speed $\frac{n}{b}$ will also alter by a nearly constant amount. While a length of 3,14 d is wound on, the bobbin travels a length δ, up or down. As the number of windings during the time the first layer is wound on is $= \frac{L}{3{,}14\,d}$ per minute, the bobbin will have to move $\delta \times \frac{L}{3{,}14d}$ per minute during this time; or the velocity of the bobbin per minute $v = \delta \times \frac{L}{3{,}14\ d}$ .... (6)

For the second layer d changes into $d + \delta$; therefore the new value of the velocity, v_1

$$v_1 = \delta \times \frac{L}{3{,}14\ (d + \delta)}\ \cdots\cdots\cdots\cdots\ (7)$$

For the third layer we have

$$v_2 = \delta \times \frac{L}{3{,}14\ (d + 2\ \delta)}$$

In general for the $(x + 1)$th layer of thread, the vertical velocity of the bobbin is—

$$v_x = \delta \times \frac{L}{3{,}4\ (d \times x\ \delta)}\quad \ldots\quad \ldots\quad (8)$$

From the equation 8 it is evident that the divisor of the right side increases by a constant amount for each successive layer ; the right side and the value of v grows also less by an approximately constant amount. This is not mathematically correct, but sufficiently so for all practical purposes.

The length of each layer of thread measured on the side of the bobbin is less by δ than the preceding one ; therefore if the length covered by the first layer is l, that by the second will be $l_1 = l - \delta$, by the third $l_2 = l - 2\ \delta$, that by the $(x + 1)$th will be

$$l_x = l - x\ \delta\quad \ldots\quad \ldots\quad (10.)$$

Therefore, also as regards the lift of the bobbin, a decrease by a constant amount takes place.

If we recapitulate the various movements, there is consequently

n for the draw-rollers constant.

n for the spindle constant.

n for the bobbin uniformly increasing.

v (the velocity of the bobbin is the vertical direction) uniformly decreasing and alternating.

l the length of the vertical movement (lift) uniformly decreasing.

To show how these various movements are brought about, we give a description of a roving frame, and shall afterwards come back upon the slubbing and intermediate frames.

The driving shaft A of the machine (*Fig*. 1, *Pl*. VII), and *Fig*. 1, *Pl*. VIII) must make 350 revolutions. If it carries a 12in. pulley, the diameter of the pulley on the mainshaft must be

$$\frac{350 \times 12}{132} = 31{,}81$$

On the shaft A there is, firstly, a wheel a of 33 teeth, driving by a carrier wheel another a_2 of also 33 teeth on the front spindle shaft B. The latter, therefore, also makes $\frac{350 \times 33}{33} = 350$ revolutions.

The spindles are placed in two rows, and the second spindle shaft B_1, also carries a wheel of 33 teeth, taken round by the former, so that it makes the same number of revolutions.

Each of these shafts drives a row of spindles, and carries for each spindle a wheel a_4 with 60 teeth, while the wheels a_5 on the spindles have 21 teeth. For the spindles, therefore, $n =$

$$\frac{350 \times 60}{21} = 1000$$

The two spindle shafts turn in opposite directions; but in order to have all spindles turning in the same way, they are placed as shown in *Fig*. 4, *Pl*. VIII, viz., one row to the right, and the other to the left of its shaft.

The shaft A further carries a pinion b with 19 teeth, driving by a carrier wheel b_1 a wheel b_2 with 52 teeth on the shaft of the driving cone. The latter makes

$$\frac{350 \times 19}{52} = 127{,}88 \text{ revolutions.}$$

A wheel c of 68 teeth on the shaft of the driving cone gears with another c_1 of 96 teeth on the front roller D next to the spindles, making

$$\frac{127.88 \times 68}{96} = 90{,}58 \text{ revolutions.}$$

As the diameter of the roller. is $1\frac{1}{4}$in., its circumferential velocity, or the length of slubbing fed per minute into the spindle is 90,58 × 3,925 = 355,5 inches. A pinion c_3 of 28 teeth (*Fig.* 3, *Pl.* VIII) drives a wheel of 90 teeth ; connected to which is another pinion c_4 with 28 teeth, driving the back roller by a wheel of 56 teeth. n for this roller, consequently =

$$\frac{90,58 \times 28 \times 28}{90 \times 56} = 14,31$$

The diameter and therefore also the circumference of this back roller being the same as that of the front roller, the circumferential velocity of the former is

$$3,925 \times 14,31 = 56,166$$

The draught between the two is

$$\frac{355,5}{56,166} = 6,33 \text{ or } 6\tfrac{1}{3}$$

The back roller carries a wheel c_6 of 30 teeth, driving by a carrier wheel c_7 and a wheel c_8 of 22 teeth, the centre roller D_1, which accordingly makes $\frac{14,31 \times 30}{22}$ 19,51 revolutions. Its diameter being 1 inch, the circumferential velocity is 19,51 × 3,14 = 61,35.

The draught consequently takes place almost entirely between the centre and front roller, while the back roller serves more for guiding the slubbing. To avoid the breakage of the slubbing, the distance from centre to centre of the front and centre roller, must be not more than the length of the staple of the cotton which is worked, so that each fibre is always held at least at one end.

The three lower rollers are fluted, and against each of them a top roller is pressed by weight and thus taken round by contact with the lower one. For the middle and front pair, the top rollers are covered with leather, while the top back roller is also fluted, in order to have a stronger hold on the cotton.

The bobbins receive their motion from the wheel e, the number of revolutions of which must increase by a constant number for each alteration in the diameter of the bobbin as shewn before. This uniformly accelerated motion is produced by a cone-motion in connection with a differential wheel mechanism.

The cone F_1 is driven from the cone F. The smallest diameter of each cone is 3in., the largest 6in., their length 30in. They are also rotatory surfaces of hyperbolic curve, F being concave and F_1 convex. They must be so constructed that in shifting the strap towards the top end of F, the number of revolutions of the shaft E

increases in proportion to the length the strap has been moved, *i.e.* if n for E increases by 5 when the strap is shifted 1 inch, it must increase by 15 if the strap is shifted 3 inches.

The shaft E carries a pinion of 26 teeth, driving the wheel d_1, ($t = 48$) and thereby the upright shaft F; on the latter a pinion d_2 of 17 teeth is fixed, working into the wheel e_1 ($t = 120$.)

If the strap is in its extreme position to the right, where its centre traces a circle of 6in. diameter on F, and one of 3in. diameter on F_1, the wheel e_1 makes the following number of revolutions:

$$\frac{127{,}88 \times 6 \times 26 \times 17}{3 \times 48 \times 120} = 19{,}626.$$

If, on the contrary the strap occupies its extreme position to the left, n for e_1 becomes

$$\frac{127{,}88 \times 3 \times 26 \times 17}{6 \times 48 \times 120} = 4{,}906.$$

These are the extreme limits for the number of revolutions of the wheel e_1.

The differential wheel mechanism has the following arrangement: e_3 is keyed on the shaft A; the two wheels marked e_2 have their bearings in the body of the wheel e_1; the wheel e_4 is in one piece with the wheel e. This piece $e\ e_4$ as well as e_1 turn loosely on the shaft A.

The two wheels e_2 are exactly alike; and e_3 is an exact counterpart of e_4. If the wheel e_1 is kept stationary, and e_3 turned once round in the direction of the arrow, the wheel e_4 will also be turned once round through the wheels e_2 gearing simultaneously with e_3 and e_4, but in the contrary direction to e_3. It would therefore, if nothing else interfered, make the same number of revolutions as A, or 350. If the wheel e_3 is drawn back, and if the two wheels e_2 are fixed in their places so that they cannot revolve, then on turning the wheel e_1 once round in the direction of the arrow, the wheel e_4 will also be turned once round, the tooth of one of the wheels e_2 just engaged with e_4 acting as a driver; e_4 consequently turns in the same direction as e_1.

If we now bring the wheel e_3 in gear again, and keep it stationary, but let the wheels e_2 revolve freely round their axles, then for one revolution of the wheel e_1, in the direction of the arrow, the wheels e_2 will roll once round e_3, and as this is kept stationary, the wheels e_2 turn round their axles $\frac{t \text{ of } e_3}{t \text{ of } e_2}$ times. Thereby the wheel e_4 is turned; its number of revolutions being $\frac{t \text{ of } e_2}{t \text{ of } e_4}$ times that of e_2, consequently as e_3 and e_4 have the same number of teeth, e_4 is turned

once round; the number of teeth of e_2 is therefore immaterial. The direction of this revolution is the same as that of e_1, therefore the two revolutions of the wheel e_4 caused by turning e_1 once round, are opposed in direction to the one caused by turning the wheel e_3.

The actual number of revolutions of the wheel e_4 therefore follows to be equal to the number of revolutions of e_3, less the double number of revolutions of e_1.

If we now proceed from the position of the strap farthest to the right, n for e_4 is $= 350 - (2 \times 19{,}626) = 310{,}748$.

If the strap is in its extreme position to the left, n of e_4 is $=$

$$350 - (2 \times 4{,}906) = 340,\ 188$$

As e_4 and e form one piece, these two valves are the limits between which the number of revolutions of e can vary.

The wheel e has 54 teeth, and drives by the two carrier wheels e_5 and e_6, the wheel e_7, and thereby the shaft G; e e_7 and e_8 have the same number of teeth, therefore n for the two shafts G and G_1 is equal to the number of revolutions of the wheel e. Every bobbin is driven from G or G_1 by a wheel e_9, having 60 teeth, while the wheel e_{11} on which the bobbin is fixed has 21 teeth. Two small pins are fastened in the wheel e_{11}, which fit into grooves on the bobbins, and so take them round. Therefore the least number of revolutions of the bobbins during the first layer of thread is $= \frac{310{,}748 \times 60}{21} = 887{,}85$,

and the greatest $\frac{340{,}188 \times 60}{21} = 971{,}965$.

The equation (1) was

$$L = 3{,}14\, d \times \left[\left(\frac{n}{s}\right) - \left(\frac{n}{b}\right) \right]$$

If we now introduce the values, taking the diameter of the bobbin $= 1\frac{3}{16}$in. $= 1{,}1875$, we find

$$L = 3{,}14 \times 1{,}1875 \times (1000 - 887{,}85)$$
$$L = 3{,}72875 \times 112{,}15$$
$$L = 418{,}179.$$

This length of 418,179 inches receiving 1000 twists, one inch receives $\frac{1000}{418{,}179} = 2{,}39$ twists.

The length delivered by the front draw box roller was only 355,5in. per minute, consequently 62,679 inches more are wound on than are supplied, or in other words those 355,5 inches are during the process

of winding stretched to 418,179 inches. Besides the draught in the drawbox therefore another draught of $\frac{418,179}{355,5} = 1,176 = 1\frac{7}{40}$ takes place. The total draught is now

$$\frac{418,179}{56,166} = 7,44.$$

which number is also obtained by multiplying 6,33 by 1,176.

If this draught between the front roller and the bobbin is to be avoided, (which must necessarily be done with short staple cotton), either bobbins of a smaller diameter may be used or the circumferential velocity of the front roller must be increased.

If we take bobbins of $1\frac{1}{8}$ diameter, L becomes $=$ $3,14 \times 1,125 \times 112,15 = 396,17$ whereby the draught decreases to

$$\frac{396,17}{355,5} = 1,1144$$

A bobbin of $1\frac{1}{16}$in. $= 1,0425$in. makes the value of $L = 374,159$.

If the diameter is $=$ 1in., L becomes 352,12, therefore about $3\frac{1}{2}$ inches less than the length delivered by the front roller. This difference is however equalized by the diminution in the length of the roving, in consequence of the twisting, so that also in this case a regular winding-on takes place without the roving becoming slack.

By using bobbins of less diameter the production of a spindle is lessened in regard to the length, although the weight remains the same.

If this is to be avoided, the front roller must be made to revolve quicker, which may be done by either diminishing the number of teeth of the wheel with 96 teeth on the front roller, or by increasing that of the driving wheel with 68 teeth.

It is best to change both wheels; by taking for instance two wheels of 72 and 90 teeth, the circumferential velocity of the front roller becomes $= \frac{350 \times 19 \times 72}{52 \times 90} \times 3,14 \times 1,25 = 401,5$.

The lifting motion of the bobbin is also effected from the cone motion.

On the shaft F there is a pinion f of 12 teeth, working into the wheel f_1 of 100 teeth on the shaft G_0; on this shaft is the pinion f_3 of 17 teeth, working into f_4 ($t = 50$), connected to the latter is f_5 ($t = 16$), driving by a carrier wheel f_6 the wheel f_7 ($t = 90$) and by it the shaft H.

For the first layer of thread n of H is

$$\frac{127{,}88 \times 6 \times 26 \times 12 \times 17 \times 16}{3 \times 48 \times 100 \times 50 \times 90} = 1{,}004$$

For the extreme position of the strap to the left hand, n of H is

$$\frac{127{,}88 \times 3 \times 26 \times 12 \times 17 \times 16}{6 \times 48 \times 100 \times 50 \times 90} = 0{,}251$$

On this shaft, H, a number of pinions of 18 teeth are fixed, acting upon an equal number of racks, having 18 teeth on $6\frac{3}{4}$ inches length. Connected to these racks is the carriage I_1 moving up and down on slides. This carriage contains the bearings of the shafts G and G_1 as well as of the wheels e_{11} and e_{12}, so that the bobbins and the wheels driving them share the movements of the carriage.

In commencing the first layer of thread (*Fig.* 1, *Pl.* VII. and *Fig.* 4, *Pl.* VIII.) the bobbin descends with a uniform velocity of $6\frac{3}{4}$ inches per minute, while for the extreme position to the left of the strap this velocity is only $\frac{1}{4} \times 6\frac{3}{4} = 1{,}69$in.

In *Fig.* 4, *Pl.* VIII., the empty bobbin measures 8in., and the first layer of thread 7in.; consequently the time it takes to wind the first layer on is $\frac{7}{6\frac{3}{4}} =$ 1 minute, 2,222 seconds.

On the shaft G there is another wheel, f_2, exactly like f_1; as soon as the pinion f works into f_2 instead of f_1, the shaft H revolves in the opposite direction, and the bobbin begins to rise.

On account of the vertical motion of the shaft G, the distance between A and G varies; therefore the two wheels e_5 and e_6 have their bearings in two links, oscillating on the two shafts A and G, so that when G is at the half of the lift, the axis of e_5 lies vertically under A, and when G is at its lowest position, this axis takes again the position shewn in *Fig.* 1, *Pl.* VIII.

The axis of e_5 oscillates upon A, while its distance from G is kept constant.

The reversing with the corresponding alterations in the various motions takes place in the following manner:

M (*Figs.* 1 & 2, *Pl.* VII.) is a fixed pin on which the piece L L, as well as the piece L_1 L_1 turn freely. The latter carries a pin N, the oscillating motion of which is limited by the fork N_1. The piece L_1 has on the top a round projection, forming two lugs, $p_2\,p_2$. P and P_1 are two levers oscillating upon the fixed points $p_1\,p_1$. Their ends $p\,p$ corresponding with $p_2\,p_2$ are connected by a spiral p_3, so as to be pressed against L_1.

O is a beam to which in O_4 a spiral O_1 is attached, fastened at o to the frame of the machine. This beam O is suspended by the rods o_1 o_2; both rods are passed through the piece L_1 and end in hooks o_6 o_7 in such a manner that for a downward movement of the rods the hooks rest against L_1 and obstruct this movement. Into these hooks the chains o_3 o_4 are hung, fastened at l and l_1 to the piece L.

If the piece L is turned to the right round M, l rises while l_1 falls, consequently O_2 is lifted up, while O_3 is lowered. Thereby the rod o_2 exercises a pull, and as the hook o_7 lies against L_1, the latter is also turned to the right. The pin N now comes against the left side of the fork N_1, and a further turning of L_1 is prevented, so that for a further lift of the point O_2, the point O_3 retains its position. The consequence is that the beam O turns round O_3, whereby O_4 is lifted and the spiral receives more tension, O_2 approaches the piece L_1 and the point L_3, because the latter does not change its position, o_6 consequently is lifted off L_1.

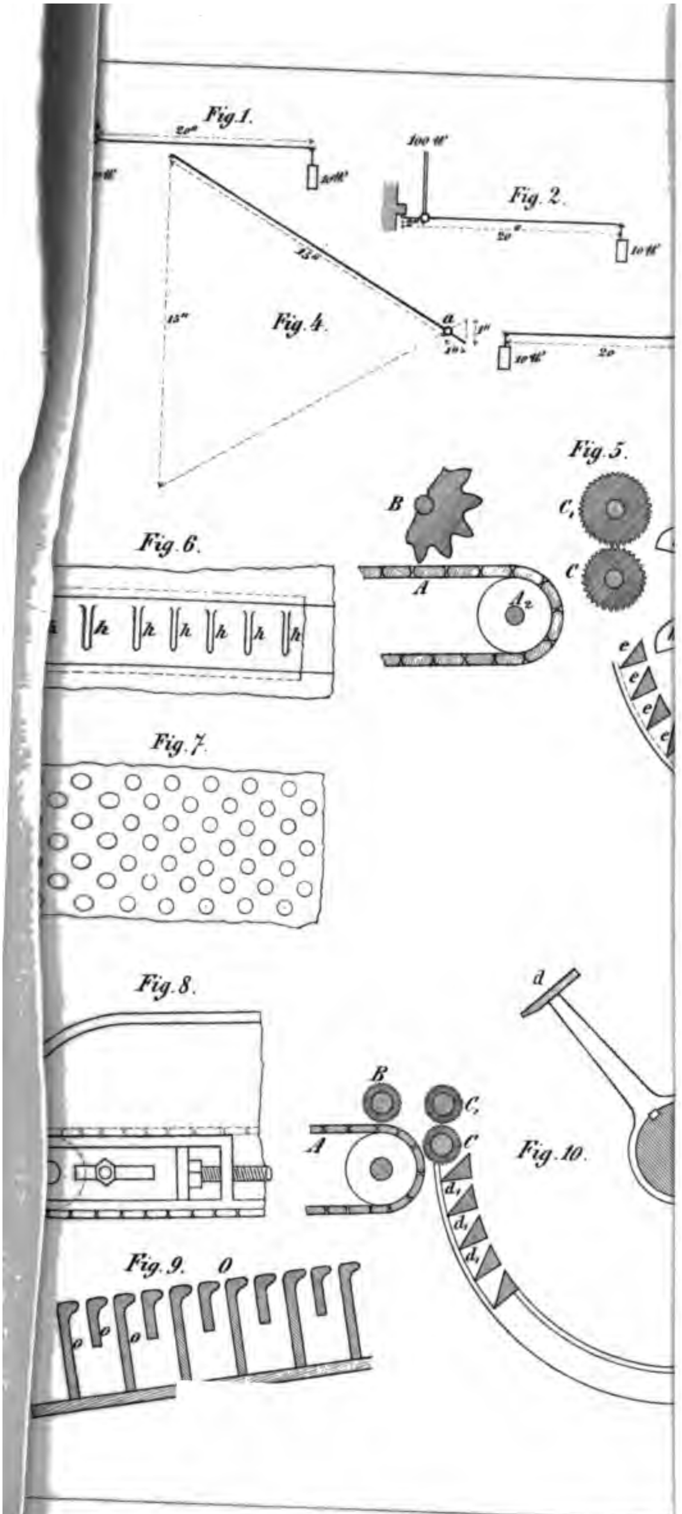
If at this moment the fork N is removed, the beam O and spiral O_1 will return to their former position of equilibrium, *i. e.* by the contraction of the spiral, the point O_4 would again become the fulcrum of the beam O_1. The point O_2 however, cannot fall, consequently O_3 and with it O_4 are lowered, O_2 forming the fulcrum. As the point O_3 falls the hook o_7 turns the piece L_1 round, so that the point L_3 makes an upward motion. As the spiral contracts suddenly, the point L_3 also makes a sudden motion in a nearly vertical direction.

The turning of the piece L is effected by the following mechanism.

Q_2 is a pair of horizontal slides fixed to the frame of the carriage and sharing its vertical motion. In *Fig.* 1, it is in its highest position, at the moment when the downward motion begins. These slide bars are moveable on the carriage, and must be so adjusted that in the mentioned position the vertical distance of the centre line from the point M is equal to half the lift of the carriage, or after making one half of its downward motion their centre line must lie in the same horizontal plane with M. Its extreme position is therefore determined by the length of the bobbin to be covered, which in this instance is 7 inches.

Q is a bar put through two lugs on L, and resting with a pin Q_1 between the slide bars. If Q_2 is lowered, the piece L is turned round M by Q.

In the position of Q_2 in *Fig.* 1, the end p of the lever P_1 is in contact with the corner p_2, and N is in contact with the right side of the fork N_1. The point O_3 is in its highest position, O_2 a little above its lowest, consequently O_4 also lifted a little, and there is a small



Lith. Anst. I. Geissendörfer, Carlsruhe.

which is connected to the strap guide for the two cones. The rack has 48 teeth for every $12\frac{3}{8}$ inches, so that after 46 reversions the strap has shifted $12\frac{3}{8}$ inches, or for each reversion $\frac{12,375}{46} = 0,269$ in. As the cone has a length of 30 inches, $\frac{30}{0,269} = 111$ reversions will take place, and accordingly 111 layers of thread will be wound on till the strap has finished its course.

The shaft U_1 carries another wheel u_5 with 16 teeth, working the rack U_6; the latter has 16 teeth in $3\frac{5}{8}$ inches, and therefore moves during 46 reversions of R_2 $3\frac{5}{8}$ inches, or for 111 a length of $\frac{111 \times 3,625}{46} = 8,747$ inches, for one reversion $\frac{8,747}{111} = 0,0788$ in. Connected with this rack is the sliding pin Q_1 and consequently the distance of Q_1 from M, or the effective length of the rod Q, is altered by the rack.

If the length of the vertical movement of Q_2 remained the same, a shortening of the rod Q would cause the oscillation of the piece L round M to increase. But as the levers P P_1 do not alter their position, this quicker oscillation of the piece L causes the reversion to take place sooner, and the length of the vertical movement of Q_2 is reduced in the same proportion as the length of Q grows less.

The machine is further provided with a self-acting stopping apparatus.

s_4 on *Fig.* 5, *Pl.* VIII. is a rod connected to the strap guide for the driving pulley of the machine. The bell crank lever s_3 s_1 is fixed on this rod, and oscillates on the pin U_3 of the pulley for weight U_4. This lever has a projection s_2 at its side.

A rod s is connected to the point L_3 so as to share its jerking motion; s_5 is a spring preventing the rod s to strike against s_2.

The rack U_5 carries a pin S, which as soon as the strap has got to the end of the driving cone, presses the rod s against the spring s_5 and overcomes its resistance. If s now is jerked upwards, it knocks against the projection s_2; the lever is turned round U_3 and the rod s_4 is moved in the direction of the arrow, whereby the strap W *(fig.* 1, *Pl.* VII.) is guided from W_0 upon the loose pulley W_1.

Fig. 6, *Pl.* VIII, shows the lateral movement of the slubbing on entering the back rollers. V is a bar, guided horizontally, and having holes v v, through each of which the ends of the slubbings of 2 bobbins are passed, and thereby the place at which they enter the rollers is determined. M forms the fulcrum of a lever V_1 connected with L, and sharing its oscillating motion. It carries a stud v_1 at

its end ; while another stud v_3 is fixed in the bar V. Both studs slide in slots of the lever V_2, swivelling on v_2. By this means the bar V shares the lateral movement of v_1, multiplied by the ratio of leverage ; it moves of course horizontally, in consequence of being guided. The slubbing accordingly moves to and fro between the rollers, whereby they are used on a larger width, and wear more evenly and slowly.

For the purpose of removing the bobbins when they are full, the spindles are turned backwards by hand by the wheel W_2. The bearing for the top of the driving cone is then lifted by a lever, and the strap becomes slack. The shaft U_1 is then turned round backwards way by the wheel U_8, whereby the weight U_4 is wound up ; the strap for the cones is shifted back to the base of the driving cone, and finally Q_1 is brought back into the position shown in *fig.* 1. Then empty bobbins are put upon the spindles, and the winding on is started afresh.

The particulars given above about the number of teeth on the change wheel, the wheels on the draw-box rollers, &c. are taken from a machine spinning No. 4, *i.e.*, 4 hanks of the rovings weighed 1 lb., and as the draught was 7,44, the number of the slubbing supplied to the machine was $\dfrac{4}{\frac{7,44}{2}} = \dfrac{8}{7,44} = 1,075$

In order to spin from this slubbing from the intermediate frame a finer or coarser number, the draught between the rollers must be altered. This is done by changing the two wheels c_2 and c_4. If instead of these wheels of 28 teeth, others of 36 are put on, the length of the slubbing taken in by the back roller per minute will be

$$\frac{90,58 \times 36 \times 36 \times 3,925}{90 \times 56} = 91,4 \text{ inches.}$$

The spindles winding on 418,179 inches, as before, the draught becomes $\dfrac{418,179}{91,4} = 4,58$—and the number of the roving delivered will be $\dfrac{4,58}{2} \times 1,075 = 2,46$.

Or, a hank weighing in the first case $\frac{1}{4}$ lbs. $= \dfrac{7,000}{4}$ grains, and 1 ley $\dfrac{7000}{4 \times 7} = 250$ grains ; the same length now will weigh $\dfrac{7000}{7 \times 2,46}$ $= 406,5$ grains.

Thereby naturally the diameter δ of the thread has been increased, the velocity v of the bobbin carriage must therefore be

correspondingly increased. This is done by replacing the pinion f_5 by another having more teeth.

For f_5, with 16 teeth, the shaft H made at the commencement of the first layer 1,004 revolutions, and the vertical motion of the bobbin was $6\frac{3}{4}$ inches per minute. If we take a pinion f_5 of 18 teeth instead, n for H becomes

$$\frac{127{,}88 \times 6 \times 26 \times 12 \times 17 \times 18}{3 \times 48 \times 100 \times 50 \times 90} = 1{,}13$$

and correspondingly v increases to 7,59 inches.

As further the increase of the rotatory velocity of the bobbin for each new layer, as well as the length by which the vertical motion of the bobbin has to be shortened, are depending on δ, an alteration in these two points has to be made. This is done by replacing the ratchet wheel u_3 by one with fewer teeth. By taking, for instance, one of 20 teeth instead of 23, U_1 will be turned round once in 40 reversions. Therefore the strap on the driving cone will be shifted for each reversion $\frac{12{,}375}{40} = 0{,}309$ inches, and the total number of layers becomes $\frac{30}{0{,}309} = 97$.

The point Q_1 now moves 8,747 inches for 97 reversions, or $\frac{8{,}747}{97} = 0{,}09$ inches for each.

Regarding the intermediate frames, the difference consists, firstly in the bobbins being made larger. If the first layer is to cover for instance a length of 10 inches, the studs l_2 must be so adjusted that the end p of the lever P is disengaged as soon as Q_1 is lifted 5 inches above the middle position on the centre M. The studs are therefore screwed, and their length can be altered.

The driving shaft of the intermediate frame best makes 200 revolutions per minute. As long as no change in the wheels is made, the number of revolutions of any revolving part of the intermediate frame is to that of the corresponding part of the roving frame as 250: 350, or as 5 : 7. Thus, for instance, the circumferential velocity of the front roller is $\frac{5}{7} \times 355{,}5 = 253{,}9$; that of the bobbin at the commencement of a new bobbin $\frac{5}{7} \times 887{,}85 = 634{,}18$.

As the roving spun on the intermediate frame is much thicker than that from the roving frame, a much larger weight of cotton is

wound in the same time upon the former than the latter. In order not to lose too much time by the frequent removal of the full bobbins, they are made correspondingly larger than for the roving frame. Naturally this causes the spindle to be subject to stronger vibrations, and to avoid any change of form it must be made stronger. Besides the spindle is made to revolve slower in order to diminish these vibrations, while the diameter of the bobbin is increased, so that the winding on can take place at the same rate as before.

According to the proportion 5 : 7 the spindles would make $\frac{5}{7} \times 1000 = 714$ revolutions per minute. If they are now made to revolve slower, while the bobbins continue to make 634,18 revolutions per minute, the length L would grow less than the velocity of the front roller, if the bobbins retained their diameter of $1\frac{3}{16}$ inches as on the roving frame.

To avoid this, the following changes are made:

The bobbins receive a diameter of $1\frac{7}{16}$ inches, $= 1,4375$ inches, so that their circumference is $3,14 \times 1,4375 = 4,51365$.

The wheel a is made with 32 instead of 33 teeth. This makes the number of revolutions of the spindles

$$\left(\frac{n}{s}\right) = \frac{250 \times 32 \times 60}{33 \times 21} = 692,63$$

$\left(\frac{n}{s}\right) - \left(\frac{n}{b}\right)$ now becomes $= 692,63 - 634,18 = 58,45$, and

$L = 58,45 \times 4,51365 = 263,8$.

The draught between front roller and bobbin is in this case =

$$\frac{263,8}{253,9} = 1,04\,;$$

while the number of twists per inch is

$$\frac{692,63}{263,8} = 2,54.$$

The number of teeth of the ratchet wheel u_3 depends of course upon the thickness of the slubbing δ; if the machine with a draught of 6,57 is to deliver thread of number 1,075, this ratchet wheel has 17 teeth, corresponding to a full bobbin of $\frac{34 \times 30}{12,375} = 82$ layers.

The slubbing frame is driven at 220 revolutions; therefore the spindles make 609,5 revolutions—the arrangement being the same as on the intermediate frame. The dimensions of the bobbins are generally the same, therefore the ratchet wheel must have less teeth on account of the greater thickness of the slubbing.

For the intermediate and roving frames, the bobbins from which the slubbing is fed between the back rollers, are put on bars in a creel, and turned round by the thread being pulled off. For the slubbing frame, there is before the back roller another roller of about 3in. diameter, driven at the same circumferential speed as the back roller, over which the web is led from the can.

The number of spindles of a machine depends upon the fineness of the yarn to be delivered; for slubbing frames it is 40 to 114; for intermediate frames 48 to 160; and for roving frames 72 to 200.

SELF-ACTING MULE.

For converting the rovings delivered by the preceding frames into yarn, three different machines are used: Throstles, self-acting mules, and hand mules.

On the throstle frames the coarsest numbers up to No. 40 can be spun, but they are rarely used for higher numbers than 30. In the same manner the self-acting mules are applicable from the coarsest numbers up to 110, but they are seldom found in use for finer numbers than 80. The finer yarns are spun on hand mules.

The throstle yarn is in comparison to the mule yarn more uniform, consequently better. On the contrary, the outlay of capital as well as the wages are higher for a number of throstle spindles than for the corresponding number of mule spindles, the produce being the same, therefore the throstle yarn is dearer to manufacture. For this reason with the exception of a few special purposes (as turkey-red dying), mule yarn is used in greater proportion, and these machines have almost entirely superseded the throstles, at least the construction of new throstles is comparatively a rare occurrence.

There are two kinds of yarn to be distinguished; twist and weft. The former is used for warps, sewing and knitting cotton; the latter only for weft, *i. e.* filling up the warps. Twist compared to weft of the same number shows greater strength; it is made of better material, and has more twists per inch of length.

The number of twists per inch depends upon the length of fibre of the cotton employed. If the quality of cotton suitable to the number is used, it may be taken as a standard that No. 60 of twist and No. 80 of weft must have each 28 twists per inch, both yarns being made of the same material.

If the number of the yarn is called N, and the number of twists per inch n, we have as a rule for twist

$$n = \sqrt{\frac{(28)^2\ N}{60}}$$

And for weft

$$n = \sqrt{\frac{(28)^2\ N}{80}}$$

Thus for instance, for No. 32 twist the number of twists is

$$n = \sqrt{\frac{28 \times 28 \times 32}{60}} = \sqrt{418} = 20{,}445$$

And for No. 40 weft,

$$n = \sqrt{\frac{28 \times 28 \times 40}{80}} = \sqrt{392} = 19{,}8$$

If worse raw material, *i. e.* material of a shorter fibre than that corresponding to the number of the yarn, is used, the number of twists thus obtained must be increased in order to attain the required firmness of thread.

The self-acting mule consists of several fixed and one moveable part; the former are the headstock, occupying about the middle of the machine; the beams on both sides of it serving as frame for the drawing rollers; the creels, for receiving the bobbins from the roving frame, marked x^2 on the drawing. At each end of the machine there is a side piece parallel to the headstock. Besides this a number of rails, friction pulleys, etc., are fastened to the floor, which will be described in their proper places. The moveable part is the carriage, on which the spindles are placed in a row, interrupted by the headstock and parallel to the draw box rollers. This carriage rests on wheels R_1 and runs in and out on rails, during which movement it is kept parallel to its original position by a special contrivance.

The spinning process of a self-acting mule is about as follows:—

The rovings obtained from the roving frame are stretched by three pair of draw box rollers and receive the required number of twists by the rotation of the spindles. During this time the carriage traverses out. It then runs the same way back, while the yarn spun during the running out is wound upon the spindles in cops of cylindrical shape, with conical ends (*fig.* 10, *Pl.* XI.) One stretch, *i. e.* the making and winding on of a length of thread equal to the length of traverse of the carriage, may be divided into 4 periods:

1st,—During the first period the carriage moves outwards; the draw box rollers supply yarn, which the spindles twist. In consequence

of the inclined position of the spindles the yarn slips over their ends and no winding on takes place.

It may here be remarked that for the sake of avoiding the formation of loops the speed of the carriage must be greater than the circumferential velocity of the front roller. The difference during one traverse is for No. 30 = 2 inches; for No. 50 = 3 inches; for No. 70 = 4 inches, &c.

2nd,—The drawing motion is stopped, the spindles continue to revolve, the carriage moves to the end of its traverse, whereby the already twisted yarn receives an additional drawing. This subsequent stretching increases with the fineness of the number. For yarns below No. 40 this second period falls out entirely; the drawing motion is not stopped until the carriage has reached the end of its entire traverse of 60 to 66 inches, at which moment the yarn has already received the required number of twists.

3rd,—The spindles are now turned backwards way, so that a short length of yarn is unwound while the copping wire is lowered, and so brings the thread to the spot on the spindle where the winding on is to begin.

4th,—The carriage runs in while the spindles revolve so often that a length of thread equal to that of the traverse is wound on.

The time required for each stretch is about 20 seconds, so that in every minute a length of 3 $\times$ (64in. on the average) is wound upon each spindle.

The various motions here occurring, each of which is produced by a special mechanism, are the following :—

1. The drawing-out motion of the carriage.
2. The taking-in motion of the same.
3. The revolving motion of the draw box rollers.
4. The revolving motion of the spindles during the twisting.
5. The turning back of them (backing off motion.)
6. The revolving motion of the same during the winding-on.

These motions are all periodical, and are thrown in and out of gear by a cam shaft.

A (*Pl.* IV, X, XI) is the driving shaft making 360 revolutions per minute, B the cam shaft, C the shaft for the drawing-out motion of the carriage, called back shaft; C_1 the shaft for taking in the carriage; E the front roller; F the tin-roller shaft, carrying the drum F_1 from which each spindle is driven by a separate band.

On the shaft A are the driving pulley A_1, and the loose pulley A_0. The width of the strap is such that when it is running full on the pulley A_1 it also drives A_0, so that as long as the machine is not stopped A_0 and the parts driven from this pulley are in continual rotation. Usually the shaft A is driven from a counter-shaft or driving apparatus, and this is thrown out of gear when the mule is to be stopped.

r is the strap guide, fixed to the bell-crank lever R oscillating upon r_1. A pin r_0 is fixed on the strap guide which is pressed against the piece m_4, fixed on the shaft B, by the spiral spring r_3, one end of which is fastened in r_2 to the lever R, while the other r_8 is fastened to the machine frame. The piece m_4 is a cylinder cut out in a peculiar manner; (*Fig.* 6, *Pl.* XI.) shows it flattened out and at the same time the positions of the pin r_0 for the 4 different periods. During one stretch the shaft B is turned four times, each time by 90 degrees. The position I of the pin r_0 corresponds with the position of the strap in *fig.* 5. During the second period the strap has already moved towards the loose pulley, while during the third and fourth it runs fully upon it. To retain the pin during the 4th period in the mentioned position the bell-crank lever oscillating upon r_5 is used. It has two set-offs, the second of which counted from the fulcrum stops the pin r_4 during the 4th period, while the first one stops it during the 1st period (*Fig.* 1, *Pl.* X.) The other arm of this lever carries a small plate r_6; r_7 is a knocker fixed to the carriage, which knocks against r_6 when the carriage runs in. Thereby the lever is turned upon r_5 so much as to let the pin r_4 loose; the spring r_3 moves the lever R to the left till r_4 is caught by the first set off, whereby the strap is brought back into the position occupied during the first period.

On the shaft A there is also a pinion a ($t = 21$) driving by a carrier wheel a_1 the wheel a_2 ($t = 52$) on the shaft E_0; the latter carries the bevil wheel a_6 ($t = 27$) driving the wheel a_7 ($t = 42$) on the front roller E.

The number of revolutions of E therefore is $= \frac{360 \times 21 \times 27}{52 \times 42}$ $= 93{,}46$.

The diameter of E is = 1in., consequently its circumferential velocity $= 3{,}14 \times 93{,}46 = 293{,}46$.

The front roller is therefore stopped by the strap being guided upon the loose pulley, but as the shaft A is turned backwards way during the third period, and as the front roller must not share this motion, the wheel a_7 is loose on E and provided with a clutchbox, so that the roller is only turned as long as this clutch is in gear with the corresponding one, which is feathered on E, so as to allow it to

slide in the longitudinal direction of E. The throwing in and out of gear is effected by the disc t keyed on B. A groove is cut into the back side of t (*Fig.* 1, *Pl.* X, *Fig.* 3 and 4, *Pl.* XI) in which the pin t_1 slides, forming one end of a lever swivelling upon t_3; the other arm of the lever ends in a fork t_4 fitting into the groove on the catch box on E. During the first period, the pin t_1 and disc t occupy the position *Fig.* 3, *Pl.* XI. As soon as the shaft B is turned to the right the pin t_1 will be forced nearer to the centre and make a movement to the right, whereby the fork is moved in the opposite direction and the clutchbox is disengaged.

On the shaft E_0 there is also a pinion a_3 ($t = 18$) which drives by a carrier wheel a_4 the wheel a_5 ($t = 69$) on the shaft C_0; a pinion a_8 ($t = 14$) on the latter drives the wheel a_9 ($t = 44$) fixed on the shaft C—

$$n \text{ of } C = \frac{360 \times 21 \times 18 \times 14}{52 \times 69 \times 44} = 12{,}06$$

This shaft C carries near its middle the grooved pulley c, and at both ends the similar pulleys c_0 and c_1. Their diameters are 8in., their circumferential velocity $3{,}14 \times 8 \times 12{,}06 = 302{,}94$.

A band, one end of which is fastened to the carriage at h_5, passes round c and over the pulley c_2 on the shaft H, and is fastened at h_4 to the carriage. The band pulleys (*Pl.* XII, *Figs.* 11 & 12) are volute at their ends, whereby an accelerated motion of the drawing-out motion can be produced, in order to facilitate the joining of their broken threads.

Their width however is so large that the part between the volutes or scrolls can be used only, and the speed of the carriage can thus be kept uniform. The scrolls c_0 c_1 correspond with the sheaves c_3 c_4 that have their bearings in the fixed side pieces; each of the bands passing over them is fastened with both ends to the carriage. By this means the carriage receives a velocity of 302,94 inches, while that of the front roller was 293,46 inches. The time required for a traverse out of 66 inches is consequently only 14 seconds, and the carriage gains upon the front roller $(302{,}94 - 293{,}46) \times \frac{14}{60} =$ $\frac{9{,}48 \times 14}{60} = 2{,}2$ inches.

For the same reasons we mentioned with regard to shaft E_1 the wheel a_9 is loose on C, and furnished with a catch box, which must be in gear with the corresponding box sliding on C, if the latter is to be turned. For this purpose the disc u on shaft B is grooved. The pin u_0 sliding in this groove forms one end of the lever turning on u_2,

while the other forked end u_3 clips the catch box on the shaft C. In figure 7, *Pl.* XI, u and u_0 are shewn in this position during the first period, when the clutches are engaged; as apparent from the drawing, they will be disengaged during the following three periods.

The pinion b ($t = 22$) is firmly keyed on the long boss of the pulley A_0 running loose on the shaft A, and gears with the wheel b_1 ($t = 34$), connected to the latter is the pinion b_2 ($t = 24$) driving b_3 ($t = 51$), keyed on the same shaft with the latter is the bevil-wheel b_7 ($t = 20$) driving b_8 ($t = 27$) on the oblique shaft C_2. The latter carries the pinion b_9 ($t = 19$) gearing with b_{10} ($t = 37$) on the shaft C_1.

$$n \text{ of } C_1 = \frac{360 \times 22 \times 24 \times 20 \times 19}{34 \times 51 \times 27 \times 37} = 41{,}7$$

The pinion b_9 is loose on C_2, and carries a he-friction-cone at its back. The corresponding she-cone slides on C_2 with a feather and groove, and if sufficiently pressed against b_9, will take it round and thereby turn the shaft. C_1.

On C_1 two scroll pulleys c_5 and c_6 are fixed; upon each of which a band is wound by the revolving motion of C_1. The bands are fastened at h_9 and h_8 to the carriage, and thus take it in; c_7 is a similar pulley, but fixed on C_1 in the opposite way to c_5 and c_6. A band wound round the latter passes over c_8, and its two ends are fastened at h_6 and h_7 to the carriage. By this pulley the shaft C_1 is turned back again during the drawing-out of the carriage.

In consequence of the volute shape of the pulleys c_5 and c_6, the taking-in motion of the carriage is at first slow, then increases in speed till it reaches its maximum, and diminishes again towards the end. The reason for this will be shewn later on in speaking of the winding-on of the threads; the decrease of the velocity at the same time serves to prevent a violent shock at the end of the traverse of the carriage. The greatest speed corresponding with the largest diameter of the volute of 11 inches is

$$3{,}14 \times 11 \times 41{,}7 = 1440 \text{ inches.}$$

The friction coupling is thrown in and out of gear by the disc u. Another pin u_1 slides in the groove of the latter, and is fixed to a lever oscillating on u_4; a rod U is joined to u_5 at one end, and at the other end to a lever turning on u_6, and clipping by its other forked end the she-cone on C_1. If B, and therewith u, is turned for 3×90 degrees, the pin u_1 is lifted; u_5 shares this motion, whereby the rod U turns the lower lever round u_6, and brings the friction cones into contact, which is again dissolved after u has made a further revolution of 90°. The coupling consequently is engaged only during the 4th period.

The spindles are made to revolve during the twisting in the following manner:—The pulley f (called the rim) with a double-grooved rim of 22in. diameter is keyed on the shaft A; f_1, f_3, f_6 are pulleys fixed to the framing; f_4 f_5 the same at the other end; f_2 ($d = 10$) a pulley fixed on F. The drum F_1 on the shaft F has a diameter of 6 inches, and the pulleys or wharves fixed on each spindle ¾in.

The double band running over f, first passes over f_1, then over f_2, and back upon f_3, from that upon f_4, and back again to f_2, then upon f_5 and f_6, and back unto f. To keep it tight the sheave f_4 can be adjusted in a horizontal direction.

The number of revolutions of the spindles consequently is

$$\frac{360 \times 22 \times 6}{10 \times 0{,}75} = 6336$$

Or, for one revolution of the rim f—

$$\frac{22 \times 6}{10 \times 0{,}75} = 17{,}6$$

The velocity with which the carriage traverses out is 302,94, the number of twists per inch therefore is

$$\frac{6336}{302{,}94} = 20{,}9 \text{ (No. 32 twist)}$$

This twisting takes place during the 1st and 2nd period, and is stopped by the strap being guided upon the loose pulley, which is done by m_4, in connection with the levers R as shown above.

The backing off motion of the spindles during the third period is produced in the following manner:—

A pinion b_4 ($t = 15$) is keyed on the same shaft with b_3 and b_7, gearing with b_5 ($t = 82$); the latter turns loose on A and makes $\frac{360 \times 22 \times 24 \times 15}{34 \times 51 \times 82} = 20{,}05$ revolutions in the opposite direction to the strap. Fixed to the body of this wheel is a friction rim, reaching inside the rim of the pulley A_1. If this friction-coupling is engaged, b_5 will take the pulley A_1 and shaft A round with it, whereby the spindles are turned in a direction opposite to their former revolutions.

The engaging is effected by the cam t on B. It has a projecting rim with a piece cut out in one place (*Fig.* 5, *Pl.* XI), against the edge of which rim the pin t_2 is pressed; t_2 is fixed in a lever that has its fulcrum in t_5 and carries a fork t_6 fitting in a groove on the boss of the wheel b_5, while the other end of the lever is pulled to the

right by a spiral spring t_7, fastened at t_8 to the framing. If t is turned so far that t_2 comes to the notch, the spring exercises its influence and turns the lever upon t_5, whereby the friction-surfaces are pressed together. This backing-off motion of the spindles takes place with a velocity of 20,05 × 17,6 = 353 revolutions per minute.

The spindles are turned during the winding-on or copping in the following way:

H is a shaft parallel to C, on which the grooved pulley h is fixed; the band running round the latter is passed over the sheave h_1 fixed on C, and its ends are fastened at h_2 and h_3 to the carriage. H carries a pinion k ($t = 17$) gearing with the quadrant k_1. During the drawing out of the carriage the quadrant is turned to the left by k, and during the taking in it makes the same way back to the right. k_1 oscillates upon k_0, and contains a screw in one of its end arms, having a little handle at the top by which the workmen can turn it. A little ratchet wheel and click fixed respectively to the screw and k_1 keeps the former in its position. The slide block k_2 forms a nut on the screw, and can be moved up and down by turning the latter. l is a lever oscillating upon l_1 with a small plate l_3 and a moveable stud l_2. l_4 is a stud fixed in the framing, against which l_3 strikes when the quadrant is turned.

F_0 is a short shaft having its bearings in the carriage. The band pulley i, the chain drum k_3, and the wheel k_4 ($t = 68$) are keyed fast upon it. i_1 is a pulley on the carriage; i_2 a half round sheave fixed to the floor. It oscillates loosely on its pivots, but is turned to the left by the weight i_3. A band fastened at i_0 to the framing passes over i and i_1, the other end being fastened to i_2.

k_5 is a wheel loose on F ($t = 24$), fixed to it is the disc k_6 carrying a click k_8; k_7 is a ratchet wheel keyed upon F; attached to the click is a small triangular plate with two pins (*Fig.* 16 and 14, *Pl.* XI). A spring (*Fig.* 14) is fastened to a stationary boss placed on F; one end of it passes between the two pins and rests against the stud of the click. If k_4 is turned in the direction of the arrow, the sheave k_6 revolves likewise, but the pin to the left of the spring is stopped in its motion by the latter, and causes the click to turn on its pivot so as to drop into the teeth of the ratchet k_7, which now transmits its rotatory motion to the shaft F and thereby to the spindles. A chain is linked to k_2, passing several times round the chain drum k_3, and is fastened to it by its other end.

When the formation of a new crop begins, the thread is wound upon the spindle itself or upon a cylinder of small circumference;

every subsequent layer is wound upon the preceding one, consequently the circumference of the cylinder upon which the thread is wound continually increases. As the length of the thread, as well as the time for taking the carriage in, remains constant, the number of revolutions of the spindles during the winding on must necessarily decrease if the breakage of the threads is to be avoided.

On beginning a new cop k_2 stands in its lowest position close to k_0, so that the point in which the chain is linked to k_2 describes a very small arc round k_0. If we suppose this movement to be $= 0$, or that k_2 remains stationary, a length of chain equal to the traverse of the carriage, or 66in. is wound off the drum k_3. The diameter of k_3 being 6 inches, the number of revolutions of the spindles is

$$\frac{66 \times 68 \times 6}{6 \times 3{,}14 \times 24 \times 0{,}75} = 79$$

66 being the length of traverse.

68 the number of teeth of k_4.

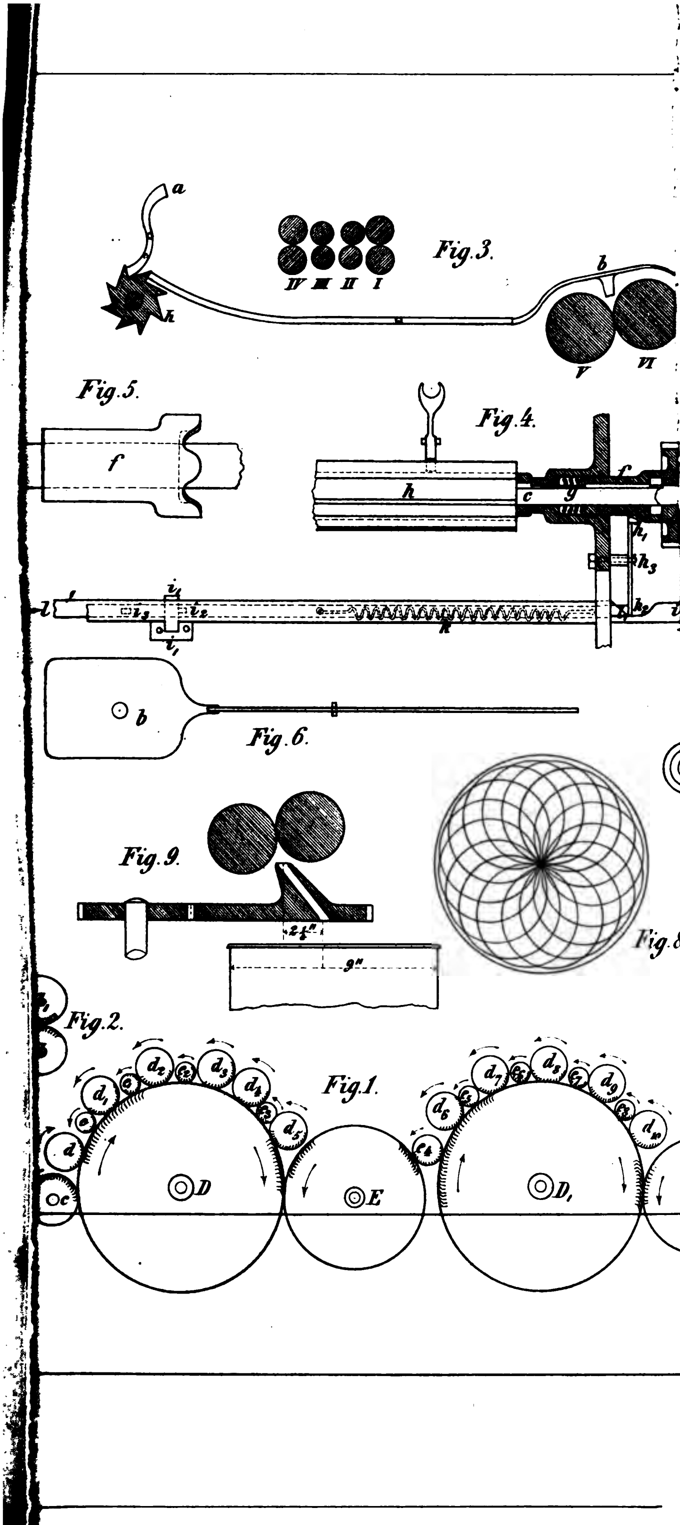
6 the diameter of F_1.

6 × 3,14 the circumference of k_3.

24 the number of teeth of k_5.

0,75 the diameter of the wharves on the spindles.

We will now suppose k_2 to be in its highest position (*Fig.* 1, *Pl.* IX.) When the carriage has reached the end of its outward traverse, the point k_2 stands nearly vertically above the shaft H, while at the end of the taking-in the quadrant has been turned so much to the right that the piece of the chain from k_2 to the drum is in a nearly horizontal position. It is now evident that the effectual length of the chain causing the revolutions of the drum is now 66 inches, less the horizontal projection of the arc described by k_2. By gradually moving the slide block k_2 from its lowest to its highest position, this length to be deducted is gradually increased, and thereby the rotatory motion of the spindles reduced in speed. When the cones of the cops which are first formed on the spindles have attained the size of the cylindrical part of the finished cops, a state of permanence begins, the spindles making after that time always the same number of revolutions during the taking-in. The screw for moving k_2 is turned by hand; various apparatus have been employed to make this regulation self-acting, but according to inquiries made of a great number of workmen in different mills, the workman always has still to correct this regulation; so that until now nothing else has been achieved by the self-regulating motions, but that the workman has to turn the screw a few times less.



Lith. Anst. Geissendörfer, Carlsruhe

plate l_3 strikes against the pin l_4, whereby the lever l is turned upon its fulcrum; the pin l_2 depresses the chain, and thereby causes the required retardation in the speed of the drum.

MOTION OF THE CAM SHAFT.

b_6 is a wheel turning loose on B, taken round by b_5, and provided with a clutch box m. The piece m_1 m_2 is connected to B by a feather and groove, m_1 being a catch box corresponding with m, and m_2 a disc with 4 teeth or stops on its face. These teeth (*Fig.* 1 and 2, *Pl.* XI), are at different distances from the centre of the disc. m_5 is a lever oscillating upon m_6 and ending in a tooth m_0 which slides upon the disc. m_3 is a spiral spring compressed between m_4 and m_2. If the tooth m_0 moves a little to the right, the spring m_3 pushes the disc m_2 towards b_6, whereby m and m_1 become engaged, and the shaft B is turned round. The tooth m_0 now slides upon the disc at such a distance from the centre as to come against the stop No. 2 after one quarter revolution, when m_2 is arrested and slides back; the clutch box is thrown out and the shaft B is stopped after turning 90°. At the end of the second period the tooth m_0 is again moved a little to the right, the catches become engaged, and another quarter revolution of B takes place, till m_0 is caught against the stop No. 3. In this manner the shaft B makes at the end of each of the 4 periods a partial revolution of 90 degrees, so as to make one entire revolution during each stretch.

L is a lever (long lever) oscillating upon L_1; one end of it L_0 is linked to the lever m_5 at m_7. Joined to L_0 is a bell crank lever, swivelling upon L_6, and carrying a small plate L_4, acted upon by the friction roller L_5 fixed to the carriage. The other end of the lever L is loaded by the weight L_2, and pulled down when there is no obstacle in the way. L_3 is a stud fastened in L.

L_7 is a pin fixed to the framing and sliding in a slot of L, so as to limit the oscillating motion of L.

N is a shaft having its bearings in the framing, on which a bell-crank lever is keyed on; one arm carries the friction roller n_5, whilst a spiral, fastened at n_4 to the framing, is attached to the other arm n_3. The hook n_2 is likewise keyed upon N, while the lever n_1 is loose upon it, and is provided with a set-off and small knock plate.

n is a stud fixed in L, which is held up during the 1st period by the catch n_1. n_7 is a knocker fixed to the carriage, striking against the knock plate on n_1.

n_8 is a lever with the knocker n_{10}; n_{11} a corresponding plate fixed to the framing. The lower end of this lever is provided with a roller n_9, connected at the same time with the lever k_{16}, oscillating upon k_{17}.

o is a curved lever keyed upon g, ending in a small surface, corresponding with the set off on n_3. n_6 is a cranked lever with a slide surface at one end, and linked with the other to n_8. It oscillates upon g and by the link causes the n_8 to oscillate upon n_9. (*Fig.* 13, *Pl.* XI.

o_2 is a bent plate to which a chain is attached at o_3. Another lever oscillates upon o_6, carrying at one end pulley o_4, at the other a plate o_7; o_5 is a weight having the tendency to move the pulley o_4 round o_6 towards the left.

o_9 is a friction pulley corresponding with o_7, carried by a lever oscillating upon o_{10}. This lever is linked to L by the rod o_{11} o_{12}, so that o_9 moves up and down with L_2.

k_9 is a sheave turning loose upon F, k_{11} a click; k_{10} a ratchet, k_{14} a pin on a lever oscillating upon k_{15} and linked to k_{16}, so that a downward movement of k_{16} moves the pin k_{14} to the left. k_{12} is a cam turning loose on the shaft F and resting against the pin k_{14}, while the pivot of the click rests against the cam. k_{13} is a spring throwing the click in and out. An eccentrically grooved pulley is attached to the sheaf k_9, upon which the chain fastened to o_3 is wound. This chain passes over o_3 and o_4 and is fastened in o_8 to the sheaf k_9. If the pin k_{14} is moved to the left, it will prevent the sheaf k_9 from returning to its former position, and detain it in one more to the left. Thereby the eccentric grooved pulley is turned so that the chain is now wound upon a large diameter. This causes the winding on to be accelerated, so that the shaft G is turned more rapidly to the right, whereby the copping wire is lowered more quickly, as will be described farther on.

The process now is the following:—

During the traverse out of the carriage, L_0 is in its lowest position; m_0 rests against the stop No. 1 on disc m_2; all parts are in the positions shewn in *Fig.* 1, *Pl.* X.

When the carriage approaches the end of its traverse, the plate n_6 comes under the friction roller n_5; the latter is lifted, causing a tension of the spring n_3 n_4 and a movement of the hook n_2 so as to bring it under the pin n. The carriage progressing, n_7 strikes against a plate on n_1, whereby the pin n is released. (To prevent n from moving too far, a small pin d is fastened in the frame which limits this movement.) The weight L_2 now begins to act

and sinks down; this causes the pin L_3 on the other end of the lever to come against a stop not shown on the drawing. Thereby the lift of the end L_0 is limited, so that the tooth m_0 only moves so far as to come against the stop No. 2 on the disc m_2; and the shaft B makes a quarter of a revolution. The strap is shifted into the place determined by the position II of the pin r_0 *Fig.* 6, *Pl.* XI, that is to say a little towards the loose pulley, but still driving the driving pulley. The draw-rollers and the drawing-out motion are thrown out of gear, while the spindles continue to revolve.

The catch supporting L_3 is withdrawn by the worm wheel a_0, as soon as the twisting is finished, which period may be lengthened as required by altering the ratio of the wheels.

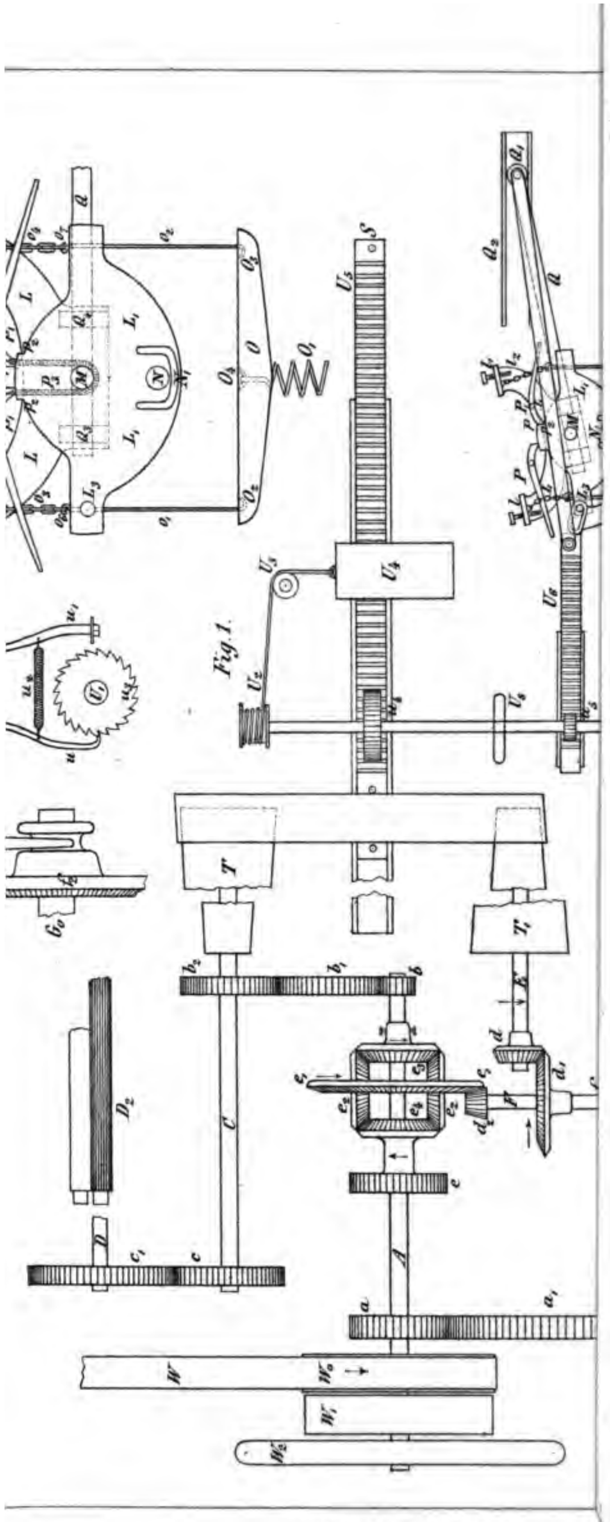
As soon as L_3 is let free the weight L_2 again lifts the ends L_0, till the pin n is caught by the hook n_2. The tooth m_0 comes after another quarter revolution of B against the stop No. 3 on m_2, and the third period begins. The strap is shifted upon the loose pulley and the spindles are stopped. But at the same time the friction cones b_5 A_1 are engaged; therefore the shaft A and the spindles turn in the opposite direction. By turning the shaft F in the opposite direction, the spring k_{13} is taken round, and pressing against the little pin, brings the click k_{11} between the teeth of k_{10}. This causes the sheaf k_9 to revolve and to wind the chain on its grooved pulley. This at first makes the pulley o_4 oscillate upon o_6 till the plate o_7 comes against the roller o_9, when the bent plate o_2 must follow the motion of the chain and the shaft G is turned.

Simultaneously with G the curved lever o is turned, which causes its outer surface to slide against n_8 till the set off on n_8 is passed. The spiral n_3 n_4 now begins to act; n_5 depresses n_6 and n_8 moves to the right till it is again stopped against o. The shaft N being thus turned a little produces an oscillation of the hook n_2 whereby the pin n is again set free, and L_2 again sinks down till the upper side of the slot in L comes in contact with the pin L_7. At the same moment o_9 falls so far as to let o_7 free; o_4 immediately oscillates to the right, whereby the tension of chain, and with it the motion of the shaft G comes to an end.

The tooth m_0 is again moved to the right so as to come against the stop No. 4. The shaft B has made another quarter of a revolution, the coupling b_5 A_1 is disengaged. The pin r_4 is stopped against the second set off of the lever oscillating upon r_5, so that the pin r_0 cannot jerk back against m_4 but is kept in the position IV. The strap consequently remains on the loose pulley.

This last turning of B causes the pin u_1 to be raised, whereby the friction coupling b_9 is engaged and the shaft C_1 is made to revolve,

II.



Lith: Anst. L. Geisendörfer Carlsruhe.

through z_{11}, and its other head passes through a nut z_{13} connected with z. The lever z_{12} oscillates upon z_{10}, and is linked to d_1 by a chain. d_1 is a small lever keyed upon the axle of the quadrant, and sharing its oscillating motion; z_7 a small ratchet keyed upon z_{10}; z_9 a click joined to z_{12}; z_8 a weight depressing the lever z_{12}. If d_1 moves to the right, z_{12} sinks down in consequence of this weight, but if d_1 is moved to the left z_{12} is raised by the chain, the click acts upon the ratchet and turns the screw z_{10}, whereby z and z_1 are moved to the right.

x is a lever fixed on G, through the end of which the faller wire passes; while x_1 keyed upon G_1 carries in a similar manner the counter faller.

S is a weight oscillating upon a stud s_5 fixed in the carriage; s_4 a chain pulley carried by the opposite end of S; s_2 a lever keyed on G. A chain fastened at one end to s_2 passes round s_4 and is attached to x_1 at s_3.

S_1 is a weight fastened below the carriage; S_3 a chain pulley keyed G_1; S_4 another pulley turning loosely on a pin fixed to the carriage; s_6 a lever keyed upon G; S_2 an inclined plane, and S_5 a friction roller, both fastened to the floor. A chain is fastened to S_1 at s_9 and after passing over the pulley S_3 is attached to S_4 at s_8; a second chain connects s_7 and s_6.

The winding-on is regulated by the movement of the faller wire, while the counter-faller serves to keep the thread tightened.

During the drawing-out x occupies the position shewn in *Fig.* 1, *Pl.* X; during the third period the faller is lowered to v_1; during the fourth period it gradually descends to v and then rises gradually to v_2, when it is suddenly jerked back into its former position.

The place of v_1 or the point to which the faller wire is lowered during the third period depends upon the angle the shaft G is forced to describe by the set off on n_8 acting upon the end of o; this depends again upon the height at which the set off on n_8 happens to be. By moving z and z_1 to the right, Z and with it the set off on n_8 is lowered; this causes the faller wire to be lowered less and less; so that the point v_1 moves toward the top end of the spindle.

The motion of the faller wire rafter reaching v_1, consequently during the fourth period depends upon the shape of the rail Z, at the beginning of this period n_9 is near to z_2 and first rises rapidly corresponding to the winding on from v_1 to v; then the rail falls gradually till near the end, where the fall is again more rapid.

The shape of the plates z and z_1 is such, that on commencing a cop the rail Z is lowered very slowly at z_2 but more quickly at z_3.

This causes the point v_1 to move slowly upwards, while the length v v_2 on which the winding on takes place rapidly increases. At first the winding on takes place on a short length of the spindle so as to form the cone (*Fig.* 8, *Pl.* XI,) and the length v v_2 gradually increases. As soon as the cone has reached the size of the cylindrical part of a finished cop, both ends of the rail Z begin to fall uniformly, so that v v_2 from this time has a constant length, and the faller wire is lowered one thickness of thread for each fresh winding on.

The slide bars z_6 are inclined, so that Z during its falling gradually moves to the right. Thereby the falling of z_3 is retarded a little, while at the same time the length v_1 v is increased.

The motion of the counter faller is the following:—

During the first period it stands on a level with the top of the spindles; during the third it falls a little so as to allow the thread to be depressed to v_1. During the fourth period it rises from the lowest position to the top of the spindles, whereby the threads are tightened, and then sinks at first slowly, and at last suddenly into its former position. When the carriage has reached the end of its outward traverse, the weight S_1 is lifted by running upon S_2. When the shaft G is turned during the third period, s_1 is lowered; the weight S begins to act and depresses x_1 and thereby the counter faller. By this means G_1 is turned a little to the right; and both chains fastened to the pulley S_4 are now slack. When the carriage begins to be taken in, the weight S_1 becomes disengaged, overcomes the influence of the weight S and turns G_1 to the left; thereby the pulley S_4 is also turned till the chain s_7 s_6 becomes tightened, and the lever x_1 is lifted above its former position. During the slow turning of the shaft G, while the winding on progresses from v to v_2, the pulley S_4 is turned back, so that the weight S_1 is lifted again, while x_1 is lowered at the same time. When the carriage has been quite taken in, the weight S_1 is lifted by the roller S_5 so far that during the jerking of the lever x the pulley S_4 and shaft G_1 can be turned back into their former position whereby the counter faller also returns to its original place.

The third period is continuously shortened firstly because o and n_8 become continually sooner engaged in consequence of n_9 being lowered; and secondly, because by the advance of the point k_{14} the turning of the shaft G begins sooner. As the pulley n_9 is lowered, k_{14} is moved to the left upon k_{15}, as shewn above, and k_9 cannot turn back as far as before; thereby a less length of the chain o_3 o_8 is wound off, respectively wound on during the next backing off, or in other words, the influence of the weight o_5 is gradually diminished, causing o_7 to come nearer to the roller o_9 after every stretch, whereby the chain receives its tension, and causes the shaft G to turn sooner.

The second period falls out entirely for numbers up to 40, as the requisite number of twists can be given to the yarn during the first period; in this case the third period immediately follows the first. The hook m_0 moves from stop 1 to stop 3; consequently the stop 2, the worm a_0 and the pin L_3 are deprived of their influence.

When the cops have attained the required size, the workman moves them to the top end of the spindles while the carriage is at the end of its backward traverse; z and z_1 are screwed back into their former position by a handle placed upon z_{10}; after disengaging the click for the screw of the quadrant, the latter is turned backwards way and k_2 brought back to its lowest position; thereby the chain fastened to k_2 becomes slack, and the shaft F_0 must be turned so as to wind the chain upon k_3 till it has the sufficient tension. If the carriage is now taken in, the thread will be wound upon the lower part of the spindle for starting a new cop, after which the finished cops are taken off.

The parallel motion of the carriage is shewn on *Fig.* 18, *Pl.* IX. y_4 y_5 y_6 y_7 are four pulleys fixed to the underside of the carriage. A band fastened with its ends to the framing or the floor at y_0 and y_1 passes over the y_4 and y_7; while a second string fastened at y_2 and y_3 passes over y_5 and y_6. The carriage rests upon a series of wheels R_1, running on rails fixed to the floor.

In order to stop the carriage at the end of its outward run some stops are fastened to the floor against which the carriage buts, and a buffer plate is attached to the centre part of the carriage, striking against the framing so as to render the stopping effectual and exact. Similar contrivances are provided for the taking-in of the carriage.

Fig. 4 and 5, *Pl.* IX, show the gearing for the drawbox. The backroller is driven from the front roller on each side of the headstock, and carries at the outside ends the wheel work for the centre roller.

The front roller passes right through the mule from one end to the other, while the other two rollers are interrupted by the headstock.

The front roller carries on each side of the headstock a pinion a_{10}, $(t = 24)$ gearing with a_{11} $(t = 120,)$ attached to the latter is a pinion a_{12} $(t = 32)$ driving the wheel a_{13} $(t = 53)$ on the back roller.

The number of revolutions of the latter consequently is

$$n = \frac{93{,}46 \times 24 \times 32}{120 \times 53} = 11{,}28.$$

Its diameter being likewise = 1 inch, its circumferential velocity is = $3{,}14 \times 11{,}28 = 35{,}419$.

The draught between the two rollers is

$$\frac{293{,}46}{35{,}419} = 8{,}28$$

The back roller carries a wheel a_{14} ($t = 32$) driving by a carrier wheel a_{15} the wheel a_{16} ($t = 24$) on the centre roller.

The latter makes $\frac{11{,}28 \times 32}{24} = 15{,}04$

revolutions. Its diameter being $\frac{7}{8}$in., the circumferential speed is

$$3{,}14 \times 0{,}875 \times 15{,}04 - 11{,}32\text{in.}$$

In this case also nearly the whole draught takes place between the centre and front roller, while the back roller serves more for guiding and taking-in the thread. The centre roller therefore must be placed so near to the front roller, that their distance from centre to centre does not exceed the length of the staple of the cotton. For short staple cotton the centre rollers, and if that is not sufficient, also the front rollers must be made of less diameter.

These three driven rollers lie below and are fluted; above each of them there is a top roller covered with leather, and pressed by weights against the bottom roller, so as to be taken round by contact. Underneath the front roller a clearer is placed, covered with flannel and also taken round, which keeps the front roller clear of cotton fibres. Upon the top rollers of the centre and back pair, a roller of larger diameter also covered with flannel is placed, which revolves freely by contact, and also serves for cleaning purposes.

The number of spindles of a mule depends upon the rooms where they have to work; it is usually about 850 for weft, and 750 for twist mules, although they have been made with as much as 1200 spindles.

The difference between twist-mules and weft mules consists in the distance at which the spindles are placed one from another. In spinning weft the cops must have such a size as to fit in a shuttle; while for twist they are made much larger in order to save time. The distance for weft spinning is usually $1\frac{1}{8}$in., for twist $1\frac{3}{8}$in.

The mules are so placed that two and two always stand opposite one another, in such a way that their spindles are facing each other. The workmen stand between them.

A pair of mules of 850 spindles each are reckoned to require two workmen and a lad.

If a change in the number of the roving supplied by the frames takes place, the draught of the drawbox may be altered for one thing. If for instance No. 32 yarn has to be spun from No. 3 roving, the draught must be made $= \frac{32}{3} = 10,66$

This is done by changing the wheel a_{12}. For a_{12}, with 32 teeth, the number of revolutions of the back roller was = 11,28. By transforming the equation (page 78) we have

$$\frac{93,46}{11,28} \times 32 = \frac{120 \times 53}{24}$$

$$\text{or } 8,28 \times 32 = 265.$$

$$32 = \frac{265}{8,28}$$

32 is the number of teeth of a_{12}, which we will designate by t; 8,28 the draught designated by dr. By substituting these letters we obtain the equation

$$t = \frac{265}{dr}$$

which is generally applicable. For the required draught of 10,66 the numbers of teeth of a_{12} must consequently be

$$t = \frac{265}{10,66} = 24,8 \text{ or } 25.$$

The draught is of course found in the reverse manner by dividing 265 by the number of teeth

$$dr = \frac{255}{t}$$

for a wheel of 30 teeth for instance, the draught becomes

$$\frac{265}{30} = 8,8333 \ldots$$

If another number of yarn is to be spun, for instance, No. 20, the number of twists per yard must firstly be diminished. According to the rule given above (page 63) this number is for No. 20 twist

$$= \sqrt{\frac{20 \times 28 \times 20}{60}} = \sqrt{261} = 16,15$$

For a stretch of 66 inches this gives $66 \times 16,05 = 1066$ revolutions of the spindles. If the carriage was to draw out as before in 14 seconds, the number of revolutions of the spindles per minute would be $= 1066 \times \frac{60}{14} = 4468.$

It was 6336 before. The coarser the yarn, the quicker the spindles may revolve. It would however be scarcely admissible to exceed 6636, therefore we will suppose that the same speed is retained also for spinning No. 20. In this case the velocity of the carriage and of the circumference of the draw rollers must of course be increased, so as to diminish the number of twists per inch. This is done by changing the wheel a_2.

The carriage traversed before 302,94 inches per minute, while a_2 had 52 teeth. In the same time the spindles made 6336 revolutions. The carriage must now traverse the same distance, during the time in which the spindles make only 4568 revolutions. The question is what number of teeth must a_2 have for this purpose.

The distance traversed by the carriage per minute is now

$$\frac{6336 \times 302{,}94}{4568} = 422\text{in.}$$

In order to obtain the number of revolutions of the shaft C, 422in. must be divided by the circumference of the pulley fixed upon this shaft, 8×3.14; we get

$$n = \frac{422}{25{,}12} = 16{,}8.$$

The equation for the drawing out of the carriage was

$$\frac{360 \times 21 \times 18 \times 14}{52 \times 69 \times 44} = 12{,}067$$

By transforming the same we obtain

$$52 \times 12{,}067 = 627{,}5$$

or in general if t is the number of teeth on a_2 and n the number of revolutions of C

$$t = \frac{627{,}5}{n} \text{ and } n = \frac{627{,}5}{t}$$

For $n = 16{,}8$, t becomes

$$t = \frac{627{,}5}{16{,}8} = 37{,}3$$

Or if we substitute instead $t = 37$, we find

$$n = \frac{627{,}5}{37} = 16{,}97,$$

and the length traversed per minute during the drawing out of the carriage $= 16{,}97 \times 25{,}12 = 426{,}97$.

In this manner the suitable alteration in the speed of the carriage can be produced.

By changing the wheel a_2 the velocity of the front roller is also altered in the same ratio, the draught of course remaining the same.

For a_2 with 37 teeth the number of revolutions of E becomes

$$n = \frac{360 \times 21 \times 27}{37 \times 42} = 131{,}35$$

and its circumferential velocity =

$$3{,}14 \times 131{,}35 = 412{,}44.$$

The ratio of the velocity of the front roller to that of the carriage remains unchanged, for

$$293{,}46 : 302{,}94 :: 412{,}44 : 426{,}28.$$

In this case the carriage therefore also gains 2,2 inches in 66in. over the front roller. This however is too much for No. 20 yarn, and it should be only 1½ inches. To make this alteration the wheel a_5 must be changed. We will however not enter farther into this subject, it being evident that if a_5 has 70 teeth instead of 69, the shaft C will run a little slower.

If the great speed of the spindles has to be reduced, which must be done for finer numbers, this is effected by changing the rim f.

We have seen that for a diameter of f of 22 inches, the spindles made 17,6 revolutions to one of the shaft A, according to the equation, (see page 68.)

$$\frac{22 \times 6}{10 \times 0{,}75} = 17{,}6$$

By transforming this equation, we find

$$\frac{22}{17{,}6} = \frac{10 \times 0{,}75}{6} = 1{,}25.$$

Or if d is the diameter of the rim and n the number of revolutions of the spindles for one of the rim, we have

$$d = 1{,}25\ n\ ;\ n = \frac{d}{1{,}25}$$

If for instance a rim of 20in. diameter is used,

$$n \text{ becomes} = \frac{20}{1{,}25} = 16$$

This naturally influences also the speed with which the spindles are turned backwards way during the third period.

It is requisite to diminish the velocity with which the carriage is taken in for finer numbers of yarn, as well as the speed of the backing off.

This is done by substituting for b_2 another wheel with less teeth.

For b_2 with 24 teeth we found n of $C_1 = 41,7$ from the equation (page 67.)

$$\frac{360 \times 22 \times 24 \times 20 \times 19}{34 \times 51 \times 27 \times 37} = 41,7.$$

$$\text{from which } \frac{24}{41,7} = \frac{34 \times 51 \times 27 \times 37}{360 \times 22 \times 20 \times 19}$$

$$\text{or } \frac{24}{41,7} = 0,576$$

in general $t = 0,576\ n$

$$n = \frac{t}{0,576}$$

where t signifies the number of teeth of b_2 and n the number of revolutions of C_1.

Thus for instance, for b_2 with 20 teeth

$$n \text{ of } C_1 = \frac{20}{0,576} = 34,72$$

Corresponding to this the number of revolutions of the wheel b_5 becomes

$$\frac{360 \times 22 \times 20 \times 15}{34 \times 51 \times 82} = 16,7$$

and the number of revolutions of the spindles per minute =

$$16,7 \times 17,6 = 294.$$

The spindles run too quick in the mule here described in regard to the wear of the machine. The quality of the yarn however does not suffer by this circumstance, so that the wear and tear is more than compensated for by the increased production obtained in that way.

Another defect is the too large diameter of the rim; 17,6 revolutions of the spindles to one of the rim is not an advantageous proportion, and it would be better to use a rim of 20 inches diameter. If this alteration was made and the production was to remain the same as before, the shaft A would have to run faster. This is effected by a change in the transmission of the motion from the main shaft to the driving apparatus from which A is driven.

The necessary number of revolutions of A is found from the following proportion, 20 : 360 : : 22 : n

$$n = \frac{360 \times 22}{20} = 396$$

The number of revolutions of the spindles per minute becomes $16 \times 396 = 6336$, and has therefore remained unchanged.

If the front roller is to retain its former velocity, the wheel a_2 must have

$$\frac{396 \times 21 \times 27}{42 \times 93{,}46} = 57{,}2 \text{ teeth}$$

or if a_2 has 57 teeth, the number of revolutions of E becomes

$$\frac{396 \times 21 \times 27}{57 \times 42} = 93{,}8.$$

As shewn before the drawing-out motion changes in the same proportion.

To avoid any change in the taking-in of the carriage, the wheel b_2 must have the following number of teeth

$$t = \frac{41{,}7 \times 34 \times 51 \times 27 \times 37}{396 \times 20 \times 22 \times 19} = 21{,}8.$$

or instead of this 22.

These are all the alterations required in this case.

The produce of this mule per spindle at the supposed rate of speed is per minute 3×66 inches, per hour, $3 \times 66 \times 60$ and per week (reckoned at 56 net hours, after deducting from the gross time half-an-hour each day for the breakage of the threads and the removal of the finished cops), it is

$$\frac{3 \times 66 \times 60 \times 56}{36 \times 840 \times 32} = \frac{11}{16} \text{lb.}$$

where 36 is the number of inches in one yard.
840 the number of yards in one hank.
32 the number of hanks in one lb.

The produce is of course larger for coarser numbers and less for finer ones, irrespectively of the decrease in the length of thread turned out for the latter in consequence of the diminished velocity of the spindles and the increased number of twists per inch.

PRODUCE AND CONSUMPTION OF THE MACHINES.

A mule spindle delivers per week of 56 working hours, (deducting half-an-hour each day for removing the finished cops.)

$$\frac{64 \times 3 \times 60 \times 56}{36 \times 840} = 21\tfrac{1}{3} \text{ hanks.}$$

if three stretchers of 64 inches each are made per minute.

If the draught is 8, each spindle will require

$$\frac{21\frac{1}{3}}{8} = 2\frac{2}{3} \text{ hanks of roving.}$$

If no draught takes place between the front rollers and bobbins of the roving, intermediate and slubbing frames, so that the length of thread wound upon the bobbin is the same as that delivered by the front roller, a spindle will turn out for each revolution of the driving shaft a length equal to the velocity-ratio between the driving shaft and the front roller, multiplied by the circumference of the latter, consequently

$$\frac{19 \times 68}{52 \times 96} \times 1{,}25 \times 3{,}14 = 0{,}2588 \times 3{,}925 = 1{,}01579.$$

If we calculate upon 54 working hours per week for the roving frame, and if the driving shaft makes 350 revolutions, each spindle will deliver

$$\frac{1{,}01579 \times 350 \times 60 \times 54}{36 \times 840} = 38{,}09 \text{ hanks}$$

while $\frac{38{,}09}{5} = 7{,}62$ hanks are taken in, if the draught is 5; but as a doubling takes place, the double length or 15,24 hanks of roving from the intermediate frame will be required.

An intermediate spindle delivers in 52 working hours

$$\frac{1{,}01579 \times 300 \times 60 \times 52}{36 \times 840} = 31{,}44 \text{ hanks}$$

the driving shaft making 300 revolutions.

If the draught is 5 it will work up in consequence of the doubling

$$\frac{2 \times 31{,}44}{5} = \frac{62{,}88}{5} = 12{,}576 \text{ hanks of slubbing.}$$

A slubbing spindle delivers in 50 working hours, while the driving shaft makes 250 revolutions,

$$\frac{1{,}01579 \times 250 \times 60 \times 50}{36 \times 840} = 25{,}19 \text{ hanks}$$

With a draught of 5 these will require

$$\frac{25{,}19}{} = 5{,}04 \text{ hanks of web from the last box.}$$

Each delivery of the last head of a drawing frame yields in 52 working hours,

$$\frac{1548{,}5 \times 52 \times 60}{36 \times 840} = 160 \text{ hanks,}$$

while 157,79 hanks of sliver from the carding engine head are taken in for each delivery of the first head, if the draught in every head is 6,03.

A carding engine driven at the rate of 150 revolutions per minute, and having a draught of $116\frac{2}{3}$, delivers in 50 working hours

$$\frac{1068,67 \times 60 \times 50}{36 \times 840} = 106 \text{ hanks of sliver.}$$

and requires

$$\frac{9,156 \times 60 \times 50}{36} = 763 \text{ yards of lap}$$

A scutcher delivers in 45 working hours

$$\frac{7,75 \times 9 \times 3.14 \times 60 \times 45}{36} = 16427,6 \text{ yards of lap.}$$

According to the above dates

1 scutcher is sufficient for $\frac{16427,6}{763} = 21,53$ carding engines.

1 carding engine for $\frac{106}{157,79} = 0,672$ deliveries of the first head.

1 delivery of the last head for $\frac{160}{5,04} = 31,7$ slubbing spindles.

1 slubbing spindle for $\frac{25,19}{12,576} = 2$ intermediate spindles.

1 intermediate spindle for $\frac{31,44}{15,24} = 2,063$ roving spindles.

1 roving spindle for $\frac{38,09}{2,666} = 14,28$ mule spindles.

Consequently 1 scutcher suffices for

21,53 carding engines.
14,468 deliveries.
458,6357 slubbing spindles.
917,27 intermediate do.
1892,328 roving do.
27000 mule spindles.

In spinning No. 32 yarn, the different machines will yield the following weight per week:

$21\frac{1}{3}$ hank of yarn weigh $\frac{21,33}{32} = 0,66 = \frac{2}{3}$lbs.

consequently 27000 mule spindles would produce 18000lbs.

A draught of 8 in the mules requires rovings of No. $\frac{32}{8} = 4$; a roving spindle accordingly would deliver $\frac{38,09}{4} = 9,52$ lbs.

If the draught of the roving frame is 5, the number of the roving from the intermediate frame will have to be on account of the doubling $\frac{2\times4}{5} = \frac{8}{5}$, or a hank must weigh $\frac{5}{8} = 0,625$lbs.; an intermediate spindle therefore delivers $31,44 \times 0,625 = 19,64$lbs.

In the same way the weight of a hank of slubbing will have to be $= 2,5 \times 0,625 = 1,5625$lbs., and a spindle delivers

$$25,19 \times 1,5625 = 39,359\text{lbs.}$$

The weight of a hank of web from the last box must be $5 \times 1,5625 = 7,8125$lbs., and each delivery yields $160 \times 7,8125 = 1250$lbs.

In consequence of the draught of 6,03 in each head of the drawing frame, the sliver from the engine head must weigh 7,93lbs. per hank; a carding engine therefore turns out $106 \times 7,93 = 840\frac{1}{2}$lbs.

The weight of the lap depends upon the amount of impurities left in the cotton by the opener and scutcher, as well as from the loss in fly. If there was no loss in weight from carding, one yard of lap would have to weigh

$$\frac{7,93 \times 116,75}{840} = 1,102175\text{lb.}$$

or 1lb. $715\frac{1}{4}$ grains.

If we estimate the loss very high, say at 5 per cent., this weight increases to

$$\frac{1,102175 \times 100}{95} = 1,16\text{lb.}$$

or 1lb. 1120 grains.

Supposing the cotton to lose also 5 per cent. in passing through the double and single scutcher, and the draught in both machines to be $= 3$, then 3,663lbs. of cotton will have to be spread upon one yard of the feed lattice of the double scutcher.

The dates given above about the produce of the various machines are to be considered as maxima, because in making the calculations we have supposed that no waste is made after the carding process.

This however, cannot be avoided in any of the machines, but the waste made by them is collected and brought to the opener to be reused, so that there is no direct loss; only the produce of the machines is lessened. We believe, however, to have taken sufficient account of this decrease in limiting the weekly working hours of the different frames.

The produce of the various machines naturally becomes less, when a finer number of yarn is to be spun. On the average a mule spindle may be calculated to deliver of

No.	lbs.
10—14	$2\frac{1}{3}$ to $1\frac{1}{3}$
20	1 to $1\frac{1}{3}$
30	$\frac{4}{5}$
40 to 60, average 50	0,5
80	0,184

In using single carding engines 40in. broad, the weekly produce may be estimated for

No.		lbs.
20	at about	700
30	„	450
50	„	350 to 400
80	„	166

The greatest amount of cotton which may be fed upon the carding engines, depends so much upon the quality of the cotton and the efficiency of the machines in the blow-room, that it cannot be determined with accuracy. The less the cards are loaded, the better is the sliver delivered. With regard to the good quality of the produce, it is therefore recommended to provide a sufficiently large number of carding engines.

We add the lists of the machines contained in three mills actually at work, from which the proportion between the different frames and spindles can be seen.

FIRST MILL.

Spinning No. 40 to 46 Weft.
„ „ 36 „ 38 Twist.
Weekly produce 11000 lbs.

1 opener
1 double scutcher
1 single scutcher
20 carding engines, 40in. on the wires
2 drawing frames (6 heads, 3 boxes)
204 slubbing spindles
504 intermediate spindles
1440 roving do
For twist: 14 mules á 720 spindles, $1\frac{3}{8}$ dist. = 10080
„ weft: 12 „ á 880 „ $1\frac{1}{8}$ dist. = 10560

Mule spindles 20640.

SECOND MILL.

33120 Spindles
504 Looms
Spinning 24 to 36 Twist
„ 24 „ 40 Weft
Weekly produce: 30,000lbs.
Motive power: 360 indicated H.P.

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1 opener
3 double scutchers
3 single „
66 carding engines, 40in.
4 grinding frames
9 drawing frames á 3 heads of 4 boxes
8 slubbing frames á 68 spindles = 544
18 intermediate frames á 84 spindles = 1512
36 roving do á 120 „ = 4320
24 mules á 720 ($1\frac{7}{8}$ distance) = 17280
18 do á 880 ($1\frac{1}{8}$ do) = 15840
168 looms $\frac{7}{8}$ wide
168 do $\frac{4}{4}$ do
168 do $\frac{9}{8}$ do

THIRD MILL.

25776 mule spindles
Spinning No. 50 average Twist
Weekly produce 11000lbs.

---

1 opener
1 double scutcher
1 single do
18 breaker cards
26 finisher cards
1 Derby doubler
2 grinding machines
4 drawing frames á 3 heads, 4 boxes
272 slubbing spindles
672 intermediate spindles
1920 roving do
36 mules á 716 spindles, $1\frac{3}{8}$ distance

In these mills single carding engines of 40in. width are used, consequently the scutchers are only 40in. wide, whereby the produce of these machines is diminished. For the same reason a draw-box turns out less than with 48in. carding engines.

We add a few remarks upon the rooms where the machines are put up.

1. The openers and scutchers are always placed in a separate room (the blow-room); the dust is generally carried off by a flue underneath the machines.

2. The carding engines and all the frames are best arranged in one room on the ground floor, though they are also frequently placed upon the first floor.

3. The mules always occupy the upper stories of the building.

As regards the motive power, one effective horse power is calculated as sufficient for driving

230 self-acting mule-spindles, or
104 throstle spindles,

including the requisite preparatory machines.

COST OF SPINNING.

It is most important and necessary for every spinner to know exactly what 1lb. of yarn costs him, so as to see at what price he can sell it and what profit he makes on it.

For this purpose it is requisite to know :

1. The price of the raw-material contained in 1lb. of yarn.

2. The cost of manufacturing the article.

The price of the raw material depends upon the loss or waste. If for instance, the raw cotton costs 18d. per lb., and loses 20 per cent. in spinning, the price of 1lb. of clean cotton is found by the rule of three. We have proportion

$$18\text{d.} : x :: 80 : 100$$

$$x = \frac{18 \times 100}{80} = 22\tfrac{1}{2}\text{d.}$$

The difficulty however lies in determining accurately the per centage of waste.

If a person has frequently carried out the process required for this purpose with attention, he will at last be able to estimate the loss with tolerable accuracy from the appearance of the raw cotton ; in fact there are many spinners who are able to do so.

The expenses of spinning are of course independent of the price of the raw material, but naturally vary according to the number of the yarn. If a mill always spins the same numbers, these expenses remain of course the same.

We give below an account of these expenses for a mill actually at work, which may be taken as a type for any other mill, and according to which it will be easy to make the necessary calculations.

THE MILL CONTAINS THE FOLLOWING MACHINES.

	£	s.	d.
4896 mule spindles ....costing	1020	0	0
Drawing frame	93	0	0
Slubbing do.	109	16	0
Intermediate frame	126	0	0
Roving frames..	345	12	0
Carding engines (clothing included)............	408	0	0
Grinding machine	16	0	0
Scutcher (bought second hand)..................	58	0	0
Willow do do	30	0	0

UTENSILS.

	£	s.	d.
Cans	24	7	6
Straps and banding	50	0	0
Bobbins	19	11	0
Skips	40	0	0
Scales, office furniture, oil-cans................	30	0	0
Total......£2370		6	6

ANNUAL CURRENT EXPENSES.

	£	s.	d.
Rent	395	0	0
Covering of cards and grinding machine	32	0	0
Small repairs of machinery	12	0	0
Gas, taxes, etc.	50	0	0
	489	0	0
To this sum must be added 5 per cent. interest and 5 per cent. for wear and tear of machinery, or together 10 per cent. on the above £2370 6s. 6d	237	0	8
The floating capital is £1200; 5 per cent. of this have to be added with	60	0	0
	£786	0	8

per year, or £15 2s. 4d. per week.

CURRENT EXPENSES FOR THE WEEK.

	£	s.	d.
Sundries as above	15	2	4
Carriage from Liverpool	1	4	0
Do. to Manchester	0	7	6
Covering of rollers	0	5	0
Straps	0	5	0
Banding	0	5	0
Oil	1	5	0
Skips	0	5	0
Travelling expenses	0	15	0
Cans	0	3	0
Bobbins	0	2	0
Wages	16	2	5
	£35	9	3

To this must be added ½ per cent. commission for the broker in Liverpool, and 3½ per cent. for the agent in Manchester. This outlay is at least covered by the sale of the waste and the overweight, arising from the moisture taken in by the yarn, after coming out of the warm spinning room. Frequently the yarn is even damped a little, so as to make it stronger. We therefore omit this item from our calculations.

The mill in question always spins No 32 twist, and the weekly produce at the rate of ⅔lbs. per spindle, (page 86) would be 3264lbs. However taking the average of several weeks, 3360lbs. were spun per week.

The expenses for these 3360lbs. of yarn are £35 9s. 3d., or for 1lb.

$$\frac{\text{£35 9s. 3d.}}{3360} = \frac{8511\text{d.}}{3360} = 2{,}533\text{d.} = 2\tfrac{1}{2}\text{d.}$$

Continuing the example given above, we find the total cost of 1lb. of No. 32 yarn by adding this expense to the cost of the raw material.

	d.
Cost of Cotton required for 1lb. of yarn	22½
Spinning expenses	2½
Cost price of 1lb. of yarn of No. 32 =	25d.

If this mill was to undertake the spinning of a higher number, the produce would be lessened, and possibly a small alteration of the wages would take place, but it would be easy to rectify the above amount of 2,533d. per lb., according to these alterations.

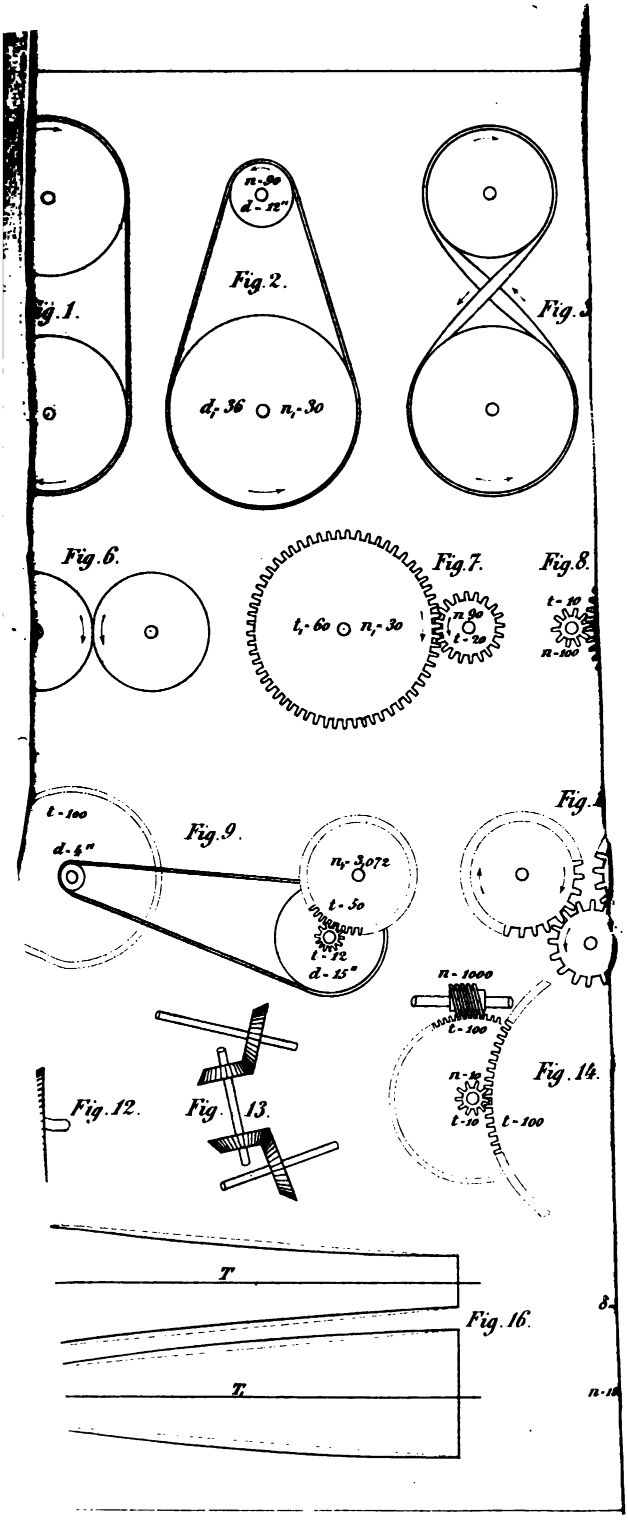
Fig. 2.
n-90
d-12"
d₁-36
n₁-30
Fig. 6.
Fig. 7.
t₁-60
n₁-30
n 90
t-20
Fig. 8.
t-10
n-100
t-100
d-4"
Fig. 9.
n₁-3072
t-50
t-12
d-15"
n-1000
t-100
Fig. 14.
n-10
t-10
t-100
Fig. 12.
Fig. 13.
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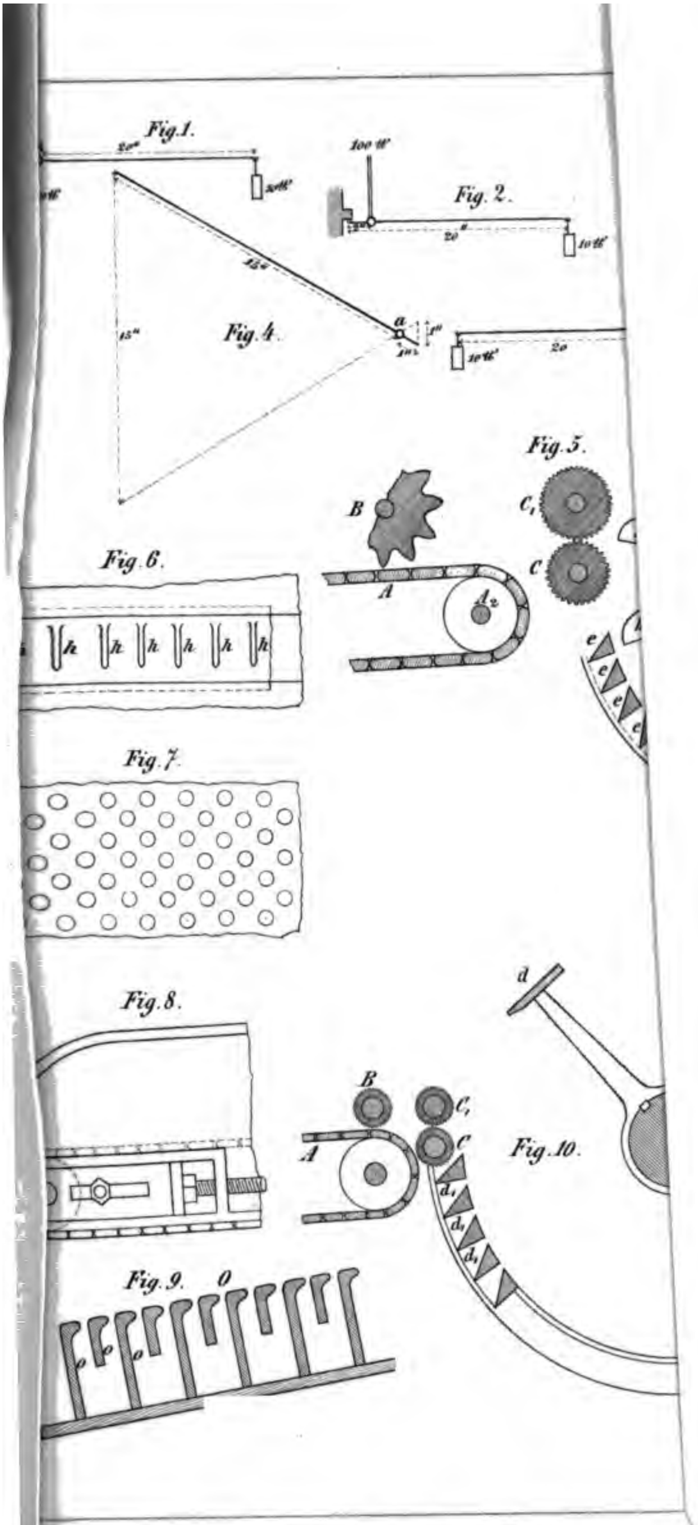

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Fig. 1.

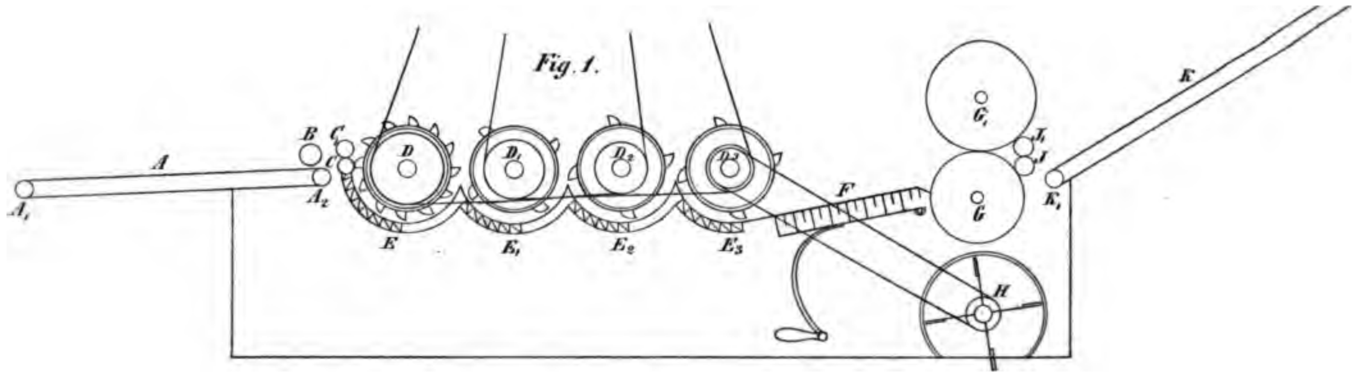
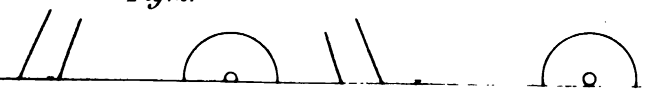


Fig. 2.



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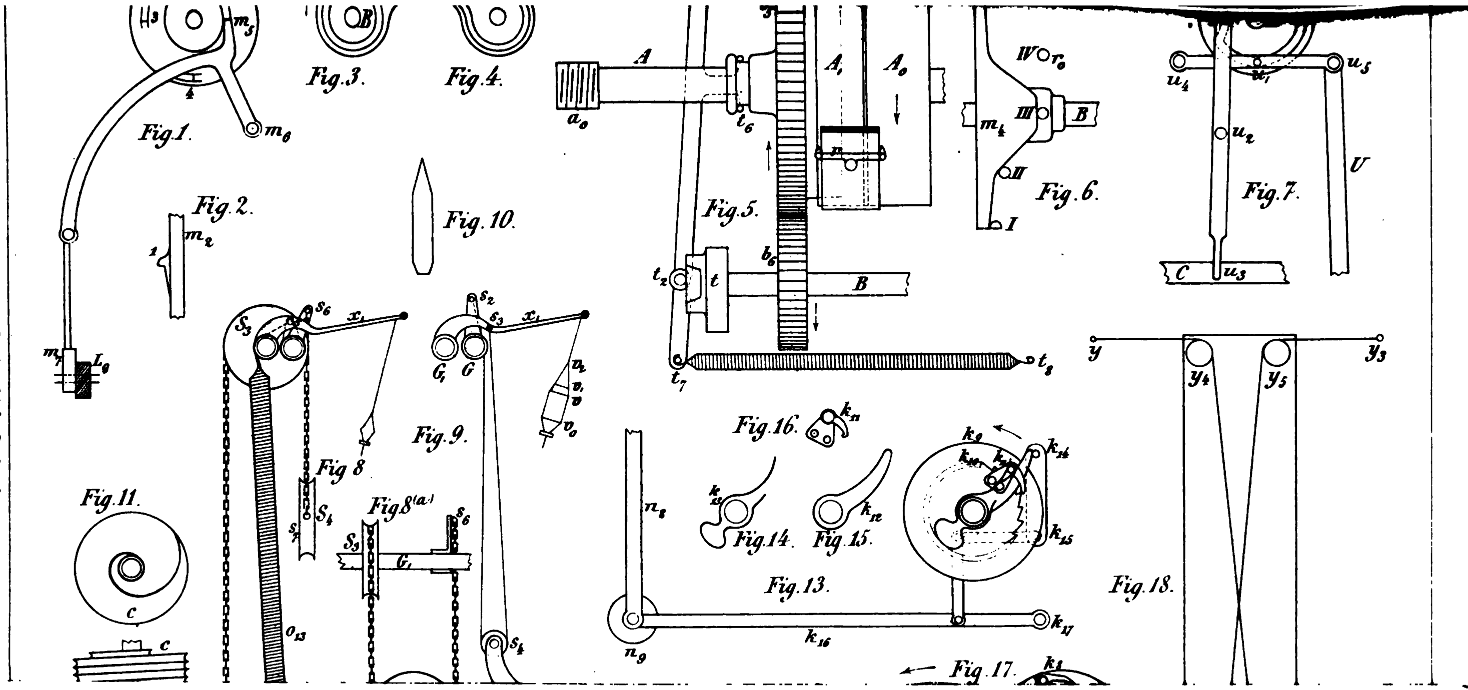

Lith. L. Geissendörfer Carlsruhe